MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

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RECENT ARTESIAN EXPERIMENTS IN INDIA.

By E. VREDENBURG, A.R.C.S., *Officiating Deputy Superintendent, Geological Survey of India.*

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CHAPTER I.

GENERAL CONSIDERATION.

During the century which is now ending, the question of a water-supply from artesian sources has from time to time attracted the attention both of the Government and of the public in India. In the year 1881 Mr. Medlicott summed up all the information available up to that date in a Memoir which was published in the Records of the Government of India,[1] and in those of the Geological Survey.[2]

Origin of water-supply.

The principle of artesian wells is now so generally understood and has been so often described that there is no need to enter into any detailed discussion of the conditions essential to their occurrence. Briefly considered they depend upon the following phenomena. The water that is poured over the land in the shape of rain is disposed of in three ways: part of it is returned to the atmosphere by evaporation; part of it runs over the surface to form rivers flowing towards the sea or towards some inland drainage basin; while the remainder sinks into the ground. It is from this subterranean source that artesian wells and also ordinary shallow wells derive their supply.

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[1] Reports on Artesian Borings in India. Selections from the Records of the Government of India, Home, Revenue and Agricultural Department. No. CLXXVIII, Calcutta, 1881.

Artesian Borings in India. Rec. Geol. Surv. Ind., Vol. XIV, pp. 205-238.

That portion which soaks into the ground usually keeps the soil and rocks moist up to a certain distance from the surface. Beyond a certain depth, which varies locally according to the amount of rainfall and the nature of the rocks, this moisture gives place to complete saturation. The water thus occupying the interstices of the rocks forms an underground reservoir, the amount stored away depending on the porosity of the rock. When the interstices take up a considerable proportion of the volume occupied by the rock, the amount of water that can be stored is proportionately great. The rock is then said to be "porous" or "permeable," while, if the opposite conditions prevail, the rock is more or less "impermeable." The degree of coarseness of texture is also to be considered, for if the interstices are very small, the retarding effects of friction and capillarity come into greater play, and in this way certain fine-grained rocks, such as clay, act as highly impermeable strata notwithstanding the fact that they can absorb a certain amount of water. On the other hand it may also happen that rocks of an impermeable texture may act as porous masses owing to their fissured or cavernous conditions. Sandstones and conglomerates constitute the most usual instances of porous formations. Some kinds of non-indurated calcareous rocks, such as chalk, are also fairly permeable. Clay is a well-known example of an impermeable medium, while the same is usually the case with crystalline sandstone or "quartzite," crystalline limestone, and the generality of igneous and metamorphic rocks, which can only act as permeable masses when they are exceptionally fissured.

Ground-water.

These underground reservoirs formed by the water contained in porous rocks may be of two sorts. The upper surface of the underground reservoir may be in direct communication with the atmosphere through the pores of the superincumbent unsaturated rock. The reservoir is then said to consist of "ground-water" or "subsoil-water." If a shaft be sunk so as to penetrate the soil deeper than the surface level of this underground reservoir, water will percolate and fill the cavity up to that level. These are ordinary percolation wells or surface wells.

Artesian conditions.

But the underground water is not always in direct communication with the atmosphere immediately above it. We know that the composition of that part of the earth nearest the surface, the "earth's crust," which is accessible to observation, is far from being homogeneous. The rock nearest the surface at one particular point may be of a highly impermeable nature, and it may extend to a depth far greater than that of the normal level of permanent saturation. Supposing there be a porous layer beneath this impermeable one, it cannot, however highly porous, receive water from the surface directly above it, because of the intervening stratum opposing itself to percolation from above. Yet, if this porous layer extends laterally to a greater distance than the overlying impermeable one, it must come into communication with the surface at some other more or less remote point. In this way it can obtain a supply of water, and if, at the place where it receives the supply, the permanent level of saturation stands at a higher altitude than the bottom of the impermeable rock that overlies it elsewhere, the porous layer may be enclosed by impermeable rocks in such a way that the water, at the place first considered, not only exerts a pressure downwards but also presses upwards on the lower surface of the bed above it. If a shaft be sunk at that place, the water will rise to a point higher than the one at which it was tapped, as soon as the impermeable layer is pierced; and if there be a sufficient difference in the altitudes of the surface at the well and at the source of supply, or fountain-head, the water may rise higher than the level of permanent saturation of the neighbourhood of the well, and may even overflow at the surface. Only to such flowing wells is the name "artesian" applied by certain authors, while according to others, the name should be given to all wells in which water rises to a higher level than that at which it was tapped. It is this latter view which was eventually taken by Mr. Medlicott: "Partial artesian action is always possible when percolation along the planes of bedding is much more easy than across them, and this seems to be a general character of stratification independently of any visible impervious beds."[1] The exclusion of all but flowing wells from the class of artesian wells is a somewhat artificial restriction. Two neighbouring wells may tap the same underground reservoir, and owing to a difference of a few feet in the altitude of the places at which they have been sunk, one of them may overflow and not the other, although all the other conditions are just the same. Moreover, a non-flowing well may, by means of pumping, prove of just as much practical utility as a flowing one, if the supply is abundant. A flowing well, on the other hand, may be of very little use if it gives a small delivery for a given diameter of the bore: the Lucknow boring struck at a depth of 1,189 feet a sheet of water under sufficient pressure to overflow at the surface; but the delivery was insignificant.

Uncertainty of nomenclature.

The conditions of artesian reservoirs are very completely discussed in a treatise by Prof. Chamberlin published by the Geological Survey of the United States.[2] Artesian reservoirs were divided by him into "perfect

Perfect and imperfect reservoirs.

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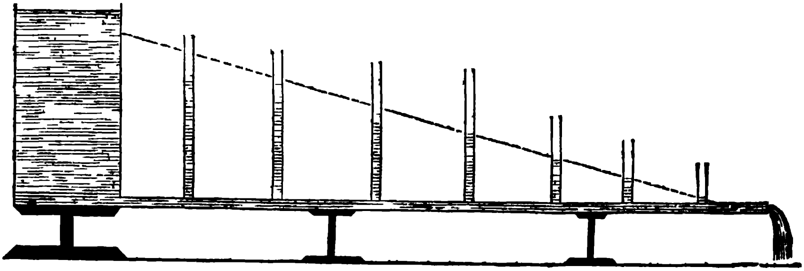
[1] Rec. Geol. Surv. Ind., Vol. XVI, p. 206.

[2] "The requisite and qualifying conditions of Artesian Wells," by T. C. Chamberlin, Fifth Annual Report of the United States Geological Survey, pp. 125-173.

reservoirs" and "imperfect reservoirs." In a "perfect reservoir" the water has no outlet at a lower level than the artificial one provided by the well. In an "imperfect reservoir" the water possesses a natural escape at a lower altitude than the well. Yet there may still be a tendency to rise owing to the resistance opposed by friction along the underground channel leading to the natural outlet. Such a condition is represented in Mr. Medlicott's experiments illustrated in the Report already referred to. The following diagram which has been several times reproduced from Daniell's Text-book of the Principles of Physics in works dealing with the present subject, gives a better idea of the facts than any description :—



Some of the artesian reservoirs that have given the most brilliant results are of the nature of "imperfect reservoirs." The Dakota sandstone, a cretaceous rock in North America, may be quoted as an example.

In the report just referred to, Mr. Medlicott also pointed out that artesian conditions are generally very different from the exceptionally favourable conditions that hold good in the typical

Basins of disturbance and of original deposition.

examples of the London or Paris basins, which are termed "basins of disturbance" in contradistinction to "basins of original deposition." He brought to notice the fact that the structure favourable to artesian action might be caused either by subsequent tilting of strata that were originally horizontal, or else that the same action might take place in undisturbed strata that have been deposited in an inclined position, as in the case of the strata occupying alluvial plains. Sedimentary rocks may be, for the purposes of the present case, divided into two principal sections: there are, first, those ancient rocks which form such a large proportion of the earth's crust, and which geologists usually classify as palæozoic, mesozoic (secondary) and tertiary. These consist of alternating strata of varying thickness, often remarkable for the small amount of variation which they exhibit over considerable areas. They have usually been deposited upon the floor of the sea at some distance from the coast, and their distribution by marine agency has resulted in their great constancy over wide areas. Owing to changes in the relative level of land and sea, or to a bending or corrugation of the originally flat surface, these strata have now come to constitute dry land and may even rise into high mountains. It is the inclined position thus assumed which often allows the formation of more or less water-tight reservoirs. The other class of strata are those that have been called diluvial, quarternary, pleistocene, or post-tertiary, the two latter terms being more commonly in use. They are newer than the strata of the first category, and consequently they rest upon them when both exist together in the same region. They merge insensibly into the alluvial deposits whose formation continues over the land at the present day. Like these recent deposits, they are generally land formations instead of being of marine origin as in the case of the majority of the older strata grouped in the first category. They often occupy a considerable horizontal surface, but they never attain the enormous thickness frequently exhibited by marine strata, and they further differ from them by having a well-marked original slope of deposition. Their composition varies a great deal from place to place, and the irregularity thus produced may be favourable to the production of artesian conditions. Volcanic formations accumulated on land are comparable to these alluvial formations in their consisting also of strata of varying permeability deposited in an inclined position. As to the floor of igneous and metamorphic rocks which carries the strata of either category, it is practically impermeable. Occasionally it has been known to yield a somewhat abundant supply of water through fissures, but such occurrences are so rare and so undependable that they cannot be taken into account in any practical scheme.

Rocks unsuited to artesian conditions.

In regions of great disturbance, sedimentary strata may be so much compressed that they become impermeable to the same extent as these igneous and metamorphic rocks. But apart from such cases, all the sediments whose relative age can be determined by means of fossils, from the oldest cambrian to the newest tertiary, have yielded artesian flows under favourable conditions. On account of the great regularity of the strata composing them, artesian reservoirs formed by the tilting of these ancient marine sediments, "basins of disturbance" in fact, lend themselves to systematic investigation in such a manner that in many cases it has been possible to foretell with a fair degree of certainty the prospects of a water-supply at any particular point. But with undisturbed alluvial deposits that are still in the same position in which they were originally laid down, we have no means of studying the concealed strata except by artificial excavations, and it is always difficult to give a decisive opinion. Wells sunk in such a formation are always more or less of an experimental nature.

In strata belonging to this category, it is sometimes difficult to decide whether a well is really or not of artesian nature. The restriction of the name to flowing wells is not a satisfactory one since it has the disadvantage of leaving outside of any well-defined category all those non-flowing wells which nevertheless are not ordinary percolation wells, but which derive their supply from an underground reservoir of water under pressure. At the same time, adopting Mr. Medlicott's definition of artesian action as the tendency of water to percolate more easily along the planes of stratification than across them, the separation from an ordinary percolation well is, especially for practical purposes, not always very distinct. The "spring wells" of the Gangetic alluvium, and some very similar ones in Gujárát, are instances of this. The alluvium of these regions contains thick beds of impervious clay known as "mota" in the North-West Provinces. These beds may occur at a depth coinciding with the level of permanent saturation, or else ten, twenty feet or more beneath it. When such a clay-bed occurs at an accessible depth at some locality where a well is needed, the well is first sunk up to the surface of this clay-bed. A narrow shaft is then excavated into the clay, and when the clay-bed is pierced, water charged with sand rushes upwards with such violence that the workmen may have barely time to escape. Captain Clibborn has given a most interesting account of such wells in a treatise on well-irrigation in the Gangetic plain, in which their peculiar action is fully explained.[1] Briefly stated, it is thus. The stratum of indurated clay that supports the well may not, and in most cases does not, extend laterally to any great distance. As therefore the water below the clay-bed is in free communication round the edges of this impervious stratum with that above it, the pressure underneath the clay stratum depends merely on its depth below the level of saturation of the ground directly above it. When the well is sunk as far as the clay-bed, the water from the saturated permeable sands above the clay is prevented by the masonry from percolating into the shaft. What may have

"Spring-wells" of the Gangetic alluvium.

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[1] Report on Well-irrigation in the North-Western Provinces and Oudh, by Captain Clibborn, B.S.C. Roorkee, 1883.

collected is baled out in order that the work of sinking the smaller tube through the clay may be proceeded with. As soon as this reaches the base of the clay, the water which was under hydrostatic pressure proportional to its depth beneath the level of saturation, gushes into the well which it fills up to that level. At first the water which flows into the well is charged with sand, and thus a cavity is formed in the sandy stratum beneath the lower orifice of the pipe that traverses the clay-bed. This cavity gets enlarged until the area of its internal surface becomes sufficient to allow water to percolate at such a rate as will replenish the well while in use, without the rate of flow being sufficient to disturb the sand, as the percolation is distributed over a sufficiently large area. If the bed of indurated clay is sufficiently thick it will support the weight of the masonry above this cavity without yielding. This explanation, the credit of which is given by Captain Clibborn to Mr. J. S. Beresford, accounts fully for the facts observed, and Captain Clibborn denies that there is anything at all of the nature of artesian action. Yet, as pointed out by Mr. Medlicott in a review of Captain Clibborn's Memoir,[1] the explanation, though fully satisfactory, is not incompatible with artesian action, so long as this is described as that of water with a greater tendency to flow along the planes of bedding than in a direction at right angles. Yet, it must be admitted that they differ but very little from an ordinary percolation well, their typical feature consisting in the fact that advantage is taken of certain natural conditions to obtain a well of moderate diameter in a permeable medium of very loose material without endangering the stability of the masonry and without any risk of silting. As pointed out by Captain Clibborn, an ordinary percolation well may be sunk in any sand however coarse and unconsolidated, if only its diameter be made large enough. He has also shown that where the clay strata do not exist, they could, leaving aside the question of expenditure, be replaced artificially by building the well upon a platform of concrete placed at some distance below the level of saturation of the ground.

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[1] Rec. Geol. Surv. Ind., Vol. XVI, pp. 205-209.

It is certain that these "spring wells" hardly answer to the popular idea of an artesian well, and naturally they would not be regarded as belonging to that category by those authors who restrict the use of the term to flowing wells. It may be suggested, that if the fact that a well is a flowing one be taken as essential to artesian conditions, a further restriction must be made so as to apply the name only to such flowing wells as are fed by a deep reservoir of water under considerable pressure. This restriction is necessary so as to exclude a certain class of wells which yield a copious flow, although not possessing any of the characters of an artesian well. Such are certain percolation wells so situated with respect to the topography of their neighbourhood, that, by means of a shallow artificial channel, the water which they collect can be discharged by gravitation alone. As an instance may be quoted the wells which supply water to the town of Rawalpindi. They derive their supply by percolation from some coarse alluvial gravels which occupy a longitudinal valley bordered by rocky ridges. This valley is situated at the foot of the hills, but at a greater altitude than the town, to which the supply of the wells is carried by gravitation alone. The wells which supply the city of Karachi, sunk in the gravels of a broad river-bed that never contains any water flowing at the surface, except in times of exceptional flood, are essentially of the same nature.

Water-supply of Rawalpindi.

Here, then, we have percolation with an abundant flow, while the "spring-wells" of the Gangetic alluvium might be taken as examples of artesian action without overflow. In fact, the difficulty which is often experienced as to whether a certain well should be classed as artesian or not, has led certain writers to discard the term entirely. This is perhaps a somewhat extreme view, for although the category cannot be defined within absolutely strict limits, yet the term is useful. It is an instance of the difficulties that are always experienced in making scientific classifications: they must always be more or less artificial, and however elaborate they can never be in complete harmony with the infinite variety of nature.

From the foregoing remarks, it follows that the "spring wells" just described, differ from the typical examples in London and Paris with regard to the situation of the well, relatively to the intake area of its water-supply. Since the clay bands which form their characteristic feature are of very limited extent, it follows that the water which they contain is, properly speaking, only "ground-water," derived from the same source as the water of ordinary percolation wells, that is, from purely local rainfall. These wells illustrate examples of local artesian action within a reservoir of water which can scarcely be called an artesian reservoir. But in the case of artesian wells like those of Paris, the porous stratum forming the natural reservoir from which they derive their supply has no communication with the surface except at its outcrop many miles away.

Special characteristics of the supply from deep artesian sources.

A very important result of this structure is that the supply of the artesian well is independent of local rainfall. Owing to its greater altitude, the collecting area is usually favoured with a more abundant rainfall than the locality at which the wells are situated. If it is sufficient to cause a constant overflow from the outcrop of the water-bearing stratum, the head of water will naturally be constant, as the artificial wells usually abstract but a small portion of the water furnished to the water-bearing stratum over the entire extent of its outcrop. Moreover, a fall of the water-level at the fountain head will not cause a corresponding loss of effective head in the well, for, owing to the retardation caused by friction, the rise of water in the well is but a fraction of what it would be otherwise. Any alteration in the level of the fountain head can only affect the outflow at the well in the same diminished proportion.

Special advantages of deep artesian sources.

These well-known features of artesian action are here alluded to because it is important to keep sight of them in discussing the capabilities of artesian wells. As already pointed out, the fact of their flowing at the surface or not is not of much importance, their usefulness, from a practical point of view, depending on an abundant and constant delivery. When the water is needed to supply a town for drinking purposes, it has this further advantage that it is free from any germs of disease. It is not, however, its applicability to domestic purposes that usually attracts public attention to artesian resources, but people have generally been struck by the achievements obtained in some countries where they have supplied the needs of irrigation. In this respect, one is apt to form an exaggerated notion of their capabilities. The imagination is easily struck by such facts as the phenomenal outflow of some of the North American wells, or by the creation of artificial oases in the midst of the Sahara. But it is necessary to keep in mind how very local these effects must remain, even at their best, and the notion, sometimes entertained, that the sinking of artesian wells would in the slightest degree afford relief during Indian famines should at once be dispelled.

Efficiency of artesian resources in deserts.

It is principally in deserts that the use which it is possible to derive from artesian water is seen to its best advantage. In a desert, no cultivation can be undertaken that depends merely upon rainfall, because the annual precipitation is insignificant and precarious. Cultivation can only be practised when that scanty rainfall, concentrated and stored by natural or artificial means, is applied to irrigation. River systems may collect from a large area so much of the rainfall as escapes evaporation, and some of their stream-beds may thus carry a perennial stream. When this reaches the plains, the water may be diverted into artificial channels and devoted to irrigation. The area thus cultivated is very small compared to that over which the rain has fallen, but it is the application to a limited area of a large proportion of the available rainfall, which renders possible agricultural operations which would be out of the question if attempted over the entire surface of the collecting area. As already pointed out, the rain water that escapes evaporation, partly flows along the surface, and partly sinks into the ground. It is this latter portion which in some instances becomes available in the shape of artesian water. Some of the recent alluvial formations peculiar to desert areas are particularly suited to the production of artesian conditions. Of late years, complete success has been achieved in the case of artesian wells sunk through such formations at Quetta, but these same reservoirs have been drawn upon since time immemorial by means of the underground channels so well known as "karez" in Baluchistan, and "kanat" in Persia, a feature which is forcibly brought to the attention of any one travelling in those regions, which would be otherwise uninhabitable. The water which supplies the underground reservoirs represents but a fraction of the amount of water that percolates into the ground, this amount itself being but a fraction of an already scanty rainfall; but compared with the supply from rivers, it has the advantage of being much less subject to variations. Such are then the capabilities and the limitations of artesian water in a desert: its yield may be locally abundant and constant enough to allow of successful irrigation, but this yield is derived from a source so scanty that under the most favourable circumstances, the area cultivated sinks into complete insignificance compared with the immensity of the surrounding desert. One of the artesian districts that have most attracted the attention of the world is that of the Oued Voir and neighbouring oases in the Algerian Sahara. According to some statistics collected in a publication issued in connection with the Paris exhibition of 1889,[1] the total yield of the wells was then 8,475 cubic feet, or 63,400 gallons per minute. The area under cultivation was not more than 4,000 acres, that is a few thousand acres amongst many thousand square miles

[1] Société Agricole et Industrielle de Batna et du Sud Algérien.

of desert. Viewed in this manner, the result must appear very small, yet it is here that the capabilties of artesian water are seen to their best advantage, since they render cultivation possible in a land which must remain otherwise absolutely unculturable.

Inefficiency of artesian resources for irrigation in humid regions.

With all other conditions remaining the same, there is no doubt that as the rainfall increases the amount available from artesian sources might be increased in about the same proportion. But the same proposition would not hold good with respect to the amount of land cultivated : with an annual rainfall of about five inches, desertic conditions must prevail, and if there is no river, the country must remain without cultivation except perhaps for a few small areas under irrigation from natural underground reservoirs scattered at intervals, just as in Baluchistan or in the Sahara. If we now turn our attention to other countries where the mean annual rainfall is thirty inches instead of five, the amount of water stored in underground reservoirs will also increase in the same proportion so long as their capacity is such that they do not overflow. But it is not so with the area cultivated : instead of the few acres of cultivated land being increased in the proportion of five to thirty, we are now dealing with countries where one-half, three-quarters, or more perhaps of the land is under cultivation. For, with increased humidity, agriculture no longer depends on purely local and exceptional conditions of storage and distribution, but the rainfall over any part of the area is sufficient to supply the local needs, making irrigation superfluous. In places where the rainfall is so abundant as to be sufficient even in years of minimum rainfall, artesian wells cease to be of any value as a means of irrigation. But there are some regions where, although the rainfall is generally sufficient, yet its amount is just on the limit of what is needed, and consequently, in years of minimum rainfall, the amount is below the requirements of the land. Hence, although irrigation is superfluous in ordinary seasons, some form of storage of water is necessary in order to save the country from ruin during the exceptionally dry years which must occur at intervals,—intervals which are irregular so far as has yet been observed. These conditions prevail over very large areas in India, and wherever sufficient provision has not been made to suit the requirements of the case, it is inevitable that ruination should visit them at intervals in the shape of the terrible calamities too well known in India during famine years. The situation of the regions thus precariously situated can be recognised by examining any map that indicates the distribution of the rainfall, such as the beautiful maps published in the Statistical Atlas of India.[1] It is probably in those regions where the average amount of annual rainfall is between twenty and forty inches that the situation is most precarious. The regions most critically stuated are,—first, the countries nearest the Indian Desert, that is portions of the Punjab, of Rajputana, of the North-West Provinces, and of Gujárát; secondly, large districts in Central India and in the Central Provinces together with part of the Deccan east of the Western Ghats, forming a considerable proportion of the Bombay and Madras Presidencies, and of the States of Hyderabad and Mysore. It is only with respect to these critically placed districts that the question of a possible supply from artesian sources for irrigation purposes is of any vital interest. As already pointed out, the desert areas are safe from severe famine, because the portion which is cultivated depends on perennial supplies of water independent of annual variations in local rainfall,—whether this supply be the mighty stream of some great river like that of the Indus, which spreads over Lower Sind the rain and melted snow of an immense catchment area in the Himaláyas, or whether it be the small but constant supply of a "karez." The more humid tracts where the rainfall is more than sufficient are equally out of question in the present enquiry. But in those vast regions where the rainfall is usually only just sufficient to supply the needs of agriculture, and where recourse must be had to some means of storage so as to tide over years of deficient rainfall, the question has been asked whether the water needed is not already stored in natural artesian reservoirs. It has already been pointed out how small is the area irrigable from artesian sources in the deserts of Algeria and Baluchistan, and it has been further argued that the water available from that source could only increase at a rate comparable with an increase of rainfall, and not comparable with the concomitant increase of culturable ground. Therefore if there occurs any failure of the rainfall in a country where rainfall is depended upon for cultivation, the portion where this deficiency could be remedied by means of artesian water would be insignificant. Another argument may yet present itself: where artesian water is regularly put to contribution for irrigation purposes, the amount which is used annually must be kept within the limits of the average annual supply to the artesian reservoir. If, on the other hand, the supply is to be drawn upon only at intervals of several years, it might be asked whether it is not possible that an artesian reservoir could exist whose structure is such that it holds in store the supply of a number of years. This might be drawn upon only in times of need, allowing the reservoir to be replenished during intervening years favoured with a better rainfall. In answer to this argument, it may first be pointed out that although such natural conditions for the reservoir are possible, and in fact do exist to a certain degree in some rare instances,[1] they are not common, for they require the coincidence of quite a number of favourable circumstances, such as an unusually large intake area, a stratum unusually porous and unusually thick, and also an

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[1] Statistical Atlas of India, Second Edition. Calcutta, 1895.

[1] Major Powell attributes partly to this cause the diminution of flow which has been observed in some of the American wells since the time when they were first sunk ; "...... it may happen that the stratum has capacity for the transmission of more water than is delivered to it. If the latter relations exist in the case of a perfect or nearly perfect reservoir, and that reservoir is tapped by numerous artesian wells, the initial discharge of water from the wells is greater than the permanent discharge. The wells in such a case draw upon a body of water which may have required years for its accumulation, and their conditions of permanent flow are not reached until this accumulation has been exhausted." Eleventh Annual Report of the Director of the United States Geological Survey, Part II, p. 262.

unusually regular structure, so that the bed should be available at a reasonable depth over a large area of the country. Under the best conditions possible, the intake area must be limited to the outcrop of the permeable stratum, and this must always be very small compared with the surface of country underlaid by the artesian reservoir, so that even if exceptional conditions of storage allowed the supply of several years to be expended in one season, the amount thus made available would still remain very small compared with the needs of the large area where irrigation is required. Besides, although the amount of artesian water available in India has scarcely received a fair test, yet it may be confidently affirmed that nowhere do such exceptional conditions occur as those outlined above. In the districts liable to famine in particular, there is not the slightest indication of anything of the sort. If we look to other countries for information, there is none perhaps from which such useful lessons can be derived as from the United States of North America. In no other region of the globe are artesian conditions developed in such a favourable manner, and nowhere perhaps have they been developed so systematically. From the oldest cambrian up to those glacial deposits which, in a geological sense, were deposited only yesterday, every system of strata has yielded artesian water in abundance. The capabilities of these resources with respect to irrigation have been very fully investigated, for, just like India, North America includes large portions in which the rainfall is insufficient or only just sufficient to provide for the needs of agriculturists. Major J. W. Powell, the late Director of the United States Geological Survey, in his "Statement before the Committee on Irrigation of the House of Representatives," in 1890 has fully examined all the aspects of the question. His report, the outcome of many years of studies specially devoted to these matters, deals with the question of irrigation considered from a theoretical, practical, and legislative point of view.[1] In this work

Examples from North America.

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[1] "The Arid Lands." Eleventh Annual Report of the Director of the United States Geological Survey. Part II, Irrigation, pp. 203-289.

Major Powell pronounces himself most unhesitatingly on the subject of the limited capabilities of artesian supplies, even with respect to such exceptional artesian reservoirs as those underlying the Great Plains, particularly the "Dakota sandstone," a rock of cretaceous age, whose permeability, regularity of stratigraphical structure, favourably situated outcrop, and immense extension make it probably difficult to match elsewhere. If such an exceptionally situated reservoir can only warrant very limited expectations, it would be unwise to build any hopes upon the Indian artesian reservoirs which can only be comparatively unimportant, and whose very existence is in many cases a matter of serious doubt. Evidently it is not to them that we must look for the serious problem of making up for the deficiency of water in years of minimum rainfall in the regions at present considered. This problem is all the more important because, if the calamity which overtakes those regions in years of drought could be avoided or at least considerably mitigated, their fertility in ordinary years is so great that they would be amongst the richest, if not actually the richest, provinces in India. With adequate means of providing irrigation during unfavourable seasons, even if only just enough to save the farmers and their stock from actual disaster, these regions where the rainfall is only just sufficient would be amongst the best situated from an agricultural point of view. To quote Major Powell's words, in the work just referred to: "Whenever in any district of country, there is just sufficient rainfall and no more, that is the best condition for that agriculture which is dependent upon rainfall. Any increase above that is injurious......What then becomes necessary is to supply additional water in seasons of drought, so there may not be a time when disaster comes to the farmer. To furnish the water necessary for these disastrous years, we have to furnish a smaller amount than in other [*i.e.*, drier] regions of country.

...... Something can be obtained from artesian wells, but not a very great amount ...... They have been bored at different places in the world and used for irrigation whenever they could be used, and it bears out the statement I make that the supply from artesian sources is always limited, is always very small, and that no great area can be irrigated thereby. If all the artesian wells in the world that are used for irrigation were assembled in one county of Dakota they would not irrigate that county.[1]"

Irrigation from shallow wells.

Since, therefore, the supply from artesian reservoirs is at best local and inadequate, we must look to some different source to provide a storage of water that will apply to the whole area concerned. This store generally exists without going to such inconveniently great depths as is often the case with artesian water: it is the reservoir formed by "ground-water," or "subsoil-water" all over the surface of the land. All over India this resource is made available through innumerable shallow wells. As pointed out in a previous paragraph, it is somewhat a matter of personal taste whether some of these wells should be called "artesian" or not, but they are to all practical purposes shallow percolation wells, and the reservoir from which they draw their supply could not properly be called artesian, however much the name might be applicable to individual wells. According to experts there is not much room for improvement either in the mode of construction or in the economical working of shallow wells as practised in India. But the system could be considerably developed, more perhaps by private enterprise than by the agency of Government, and it is, I believe, a well recognised principle that the farmers should be given every encouragement to construct new wells. Years of minimum rainfall ought to be particularly suited to this work, as it is easy to sink the wells to a good depth below the average level of saturation of the ground. A great deal was accomplished in this line during the last abnormally dry season of 1899-1900: a great many new wells have been sunk, and many old ones deepened.

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[1] *Loc. cit.*, pp. 259-260.

Irrigation from canals.

There are many places topographically so situated that wells provide the only available means of irrigation. But wherever feasible, irrigation from artificial canals deriving their supply from the perennial flow of natural river channels, or from artificial reservoirs will enhance the value of the land considerably more than irrigation from wells can do. This method, however, does not come under the scope of private enterprise, but can only be accomplished as an outcome of well-matured schemes of such vast proportions as can only be dealt with by Government. In this line India has nothing to learn from other countries, and her canals and her "tanks" have long commanded the admiration of the engineering world, ranking as models to be imitated wherever similar works are undertaken. It is, no doubt, to the extension of this system of irrigation from canals and to its thoroughly systematic application that we must look forward to the development of the agricultural possibilities of the country to their utmost degree of efficiency, and for the complete disappearance of those dire calamities which must keep recurring at fated intervals, so long as India is not adequately provided for against the difficulties caused by occasional periods of deficient rainfall. If artesian reservoirs were of any great utility in averting these disasters, it would seem strange indeed that their resources should have been neglected by a body of men of such ability as are found in the Irrigation branch of the Public Works Department. The explanation of that apparent neglect is, that such a resource does not really exist. Much has been done already in the way of reservoir and canal construction in districts liable to occasional drought. There remains certainly plenty to be done, for these works have not been developed to the same extent as in regions of permanently deficient rainfall where they are much more remunerative owing to their being constantly needed. The canals that are built in districts where the rainfall is amply sufficient in all but years of minimum rainfall do not seem at first sight to be remunerative, since they are merely of the nature of protective works, and will probably often remain idle during periods of several years. Yet, the additional value which increased security against disaster confers upon the land must in the long run amply repay the capital expended on such undertakings. Of course, the work must eventually be carried out on a gigantic scale, and is one that even the wealthiest Government cannot perform in one day; but since the ultimate source upon which all agriculture depends is the rainfall, the most economical distribution of that rainfall must eventually become the means of obtaining the most remunerative condition of agriculture. All that has been done so far in India, has been along those lines, and when the work is completed, India will find herself able to provide amply for a much more numerous population than she supports at present, without any risk of periodical starvation, and without having recourse to such desperate palliatives as emigration and other extreme measures which have to be resorted to as a remedy for the evil as it exists at present. As to artesian irrigation which is every now and then advocated as a remedy by well-meaning persons, I have endeavoured to show that by following the question to its ultimate conclusions, we find that they must have been deluded by the deceptive appearance of exceptional occurrences, and it is well to be guarded against such proposals, and not waste upon a matter, which is only of secondary importance, energies that can find better employment elsewhere.

The foregoing remarks apply only to those areas where in all but exceptional years the rainfall is sufficient for agricultural purposes. In more arid regions, agriculture depending on local rainfall alone becomes so precarious that it is not attempted. Cultivation is only undertaken where rendered possible by irrigation, and such regions do not undergo the risk of severe famine. Artesian reservoirs are of course locally of the greatest utility wherever they can provide the necessary means of irrigation; but those regions do not present problems of such urgent character and vital importance as the provinces where occasional failure of rain can bring about appalling disasters. To a still greater extent is this the case with actual deserts, where it may happen, it is true, that the only existing cultivation is from artesian sources, but such countries can only support the lives of some hundreds of men, not of millions like those whose unfortunately precarious condition has just been discussed.

Artesian resources in regions of abundant rainfall.

In those regions, on the other hand, where rainfall is always abundant, artesian reservoirs lose all importance as sources of irrigation, but may still be of great use in secondary though by no means unimportant questions, such as a supply for manufacturing or for drinking purposes. Thus confined within reasonable limits, the question of artesian supply is of the greatest interest, and is fully justified in attracting the attention of private enterprise or of public bodies such as municipalities.

Present state of the question.

It cannot be said that very much has been done in this line in India, and it is doubtful how much can be done. It may be safely asserted that throughout the length and breadth of India there is no artesian reservoir comparable to the Dakota sandstone of North America, or the regularly disposed basins of London and Paris. This has been clearly recognised since the day when the main features of the geological map were delineated. But the Geological Survey with its small staff of Officers has not yet been equal to the task of carrying out a detailed examination of that immense area to such a degree of minuteness as would allow of a definite opinion on the possible resources of underground reservoirs, whose performance might be small perhaps as compared with the examples just quoted from Europe and America, but which yet might prove very useful and welcome for local needs. Not only are there many portions of India proper which are "terræ incognitæ" in a geological sense, but enormous areas have been thrown open to geological observation in Burma and in Baluchistan which still further increase the vastness of the task. Consequently, the parts of the map that have been submitted to detailed examination are very few, as the time necessary for work of that kind can seldom be spared except for some special object like the detailed survey of a small area occupied by a coal-field. Under the circumstances, the minute examination necessary to decide these questions is quite out of the question. The delineation on the map of the areas of metamorphic rocks at once excludes certain portions from the range of research since artesian water can scarcely be expected from them. But if a geological map of India be examined, it will be noticed that an enormous area of the Peninsula is occupied by a volcanic formation known as the "Deccan trap." Practically the whole of that area is unsurveyed: we know next to nothing of that immense formation, but the mere boundary of the tract which it occupies. As to its capacity as a water-bearing formation, little is known and great differences of opinion exist. The map also shows a large area occupied by the "Vindhyan" rocks. These have received more attention than the "Deccan trap," but still in a very general manner, and very little is known regarding their behaviour as water-bearing strata. Lastly, we have scarcely any information respecting the underground structure of that immense spread of recent deposits constituting the Indo-Gangetic alluvial plain, whose strata are still in the position in which they were deposited, and no exact knowledge of which can be arrived at except from actual borings. In the opening paragraph of these notes, I mentioned that a review of the whole question as it then stood in India had been written by Mr. Medlicott in 1881. It cannot be said that the knowledge gained in the two decades that have since elapsed can allow much to be added to what he so ably discussed. Artesian problems are always so full of uncertainty that the results of actual experiment play an important part in arriving at any definite conclusions respecting subsequent trials. The experiments carried out since the publication of

Mr. Medlicott's report have not been very numerous. Most of them have been described in the publications of the Geological Survey. A short account of the most important ones is given in the following chapter.

CHAPTER II.

DETAILED ACCOUNT OF SOME RECENT EXPERIMENTS.

(1) *Baluchistan.*

Structure of recent deposits of the Quetta plain.

The most successful borings are those of Quetta. The structure of the deposits underlying the plain of Quetta has been fully explained by Mr. Oldham in a paper published by the Government and reproduced in the Records of the Geological Survey.[1] The town of Quetta is situated in the midst of a broad plain surrounded by high ranges of hills. The streams that issue from those hills carry, in times of flood, boulders and coarse detritus which they abandon owing to the diminished gradient when they enter the plain. Owing to the scantiness of the rainfall, the plain is not scoured by streams powerful enough to remove these materials, and thus shallow cones of talus material or "alluvial fans" are formed, constituting a very characteristic feature of desert regions. They all coalesce with one another and with the talus formed by the ordinary process of disintegration, forming a broad incline, the so-called "daman" which fringes the mountain ranges in Baluchistan. At the apex of each of the shallow cones the river divides itself into a number of branches very much as it would do in a "delta." These channels are usually dry, and it is only when there has been a shower that they give passage to a stream of water which bears sand and boulders if the shower has been abundant enough. The more important channels in the fan, those that are, for the time being, so situated as to collect a great amount of water, carry their burden farthest and send tongues of gravel reaching the plain. Like all rivers they are apt to shift their position, and the coarse gravels in the abandoned channels become gradually buried under the deposits of fine silt known as "loess," which are derived from the disintegration of neighbouring rocks or consist of wind-borne dust floated from afar, and which gradually get spread over the land by the slow and gentle action of rain-wash. The same process is many times repeated till the plain is occupied by a succession of irregular tongues or patches of loose permeable gravel alternating with layers of silt which are highly impermeable owing to their fine texture and argillaceous composition. The tongues of gravel decrease in coarseness as they slope towards the plain; they are entirely enclosed by the impermeable clays except at the apex of the alluvial fan where, by increasingly coarse material they all come into communication with the chaotic accumulation of boulders at the debouçhure of the river from the hills. Owing to the torrential nature of the rivers and the peculiar structure of the alluvial fans, the gradients are high, so that there is a considerable difference of level between the coarse gravels at the head of the fan, and the plain over which the deposits are distributed. Thus arises a condition which is eminently suited to artesian action. The coarse nature of the deposits at the head of the slope of the "daman" favour percolation; the water gradually finds its way into the buried tongues of gravel, and the impermeable clays which enclose these gravels prevent all natural escape, thus producing an artesian reservoir which is eminently of the "perfect" type. Where these reservoirs can be tapped they are extremely useful, since by means of them it is possible to distribute to the arid soil of the plain the relatively abundant rain that falls on the hills where it would be of no use owing to the steepness of their bare slopes.

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[1] "On the mode of occurrence and probable distribution of artesian water in the valley plains of the Quetta and Pishin District," reprinted in "Sub-recent and Recent Deposits of the valley plains of Quetta, Pishin, and the Dasht-i-Bedaolat; with appendices on the Chamans of Quetta, and the Artesian Water Supply of Quetta and Pishin." Rec. Geol. Surv. Ind., Vol. XXV, pp. 36-53.

So long as they are left to their own devices, it is not within the means of the inhabitants of these sparsely populated districts to obtain this water through artesian wells, as they do not possess suitable appliances to reach the requisite depth. But with their simple methods they can obtain the same supply by the much more laborious task of driving a horizontal gallery through the inclined beds in the lower portion of the talus. These are the works known as "karez" or "kanat" which have already been mentioned in a previous paragraph. The water is not under great pressure where the stratum containing it is penetrated by works of this kind, but the great surface of percolation in the gallery allows the collection of an abundant supply. The first attempt to tap this supply by means of a boring was made at Quetta in 1889. The experiment was eminently successful and, since then, many other borings have succeeded, while experiments of a promising nature have also been attempted in the plain of Pishin. From the irregular conformation of these deposits, the prospects of success at any particular point within the area covered by them cannot be accurately predicted. The tongues of gravel must overlap one another in a very irregular manner, and there is no means of knowing their lateral extension. At one place, a water-bearing stratum may be struck at a much smaller depth than at another, while it may also happen that the gravel may be missed entirely, which explains why some borings have been unsuccessful, though surrounded by others that have met with water-bearing strata. In fact in all artesian reservoirs like this one, consisting of recent undisturbed deposits, the only indication that can be given with any degree of accuracy is the main boundary of the area within which success is possible, but success at any particular point within that area must remain, to a great degree, a matter of chance.

The yield of a small artesian reservoir, like that of the Quetta basin, situated in a very dry region, is subject to a certain amount of variation according to differences in the amount of yearly rainfall. The flow from the karez galleries at Quetta is known to be affected to some extent by such variations, and some of them have even been known to stop flowing entirely after prolonged periods of abnormal drought.

Other localities favourably situated.

The structure of the recent alluvial deposits in the valley-plain of Quetta is by no means special to that one locality, but is common in a greater or less degree to all the talus deposits that fringe the high mountains of Baluchistan and Persia, of that arid table-land known as the plateau of Iran. At many places, the water which they contain is tapped by the karez and kanat galleries, and, no doubt, it would be available also by artesian wells. For instance, all along the mountain ranges which form the southern border of the great desert which stretches from Nushki up to the Persian Frontier, these talus deposits frequently assume enormous proportions. At a few localities far distant from one another, karez tunnels have been driven into them, and it would be worth while making an experimental boring at one of the most likely places.

Boring records of wells at Quetta.

There is not much that calls for comment in the boring records of the wells in Quetta. The deposits are too irregular to allow the identification of strata encountered in different wells. In all the borings, the same varieties of sands and clays were met with in alternating layers. The following records were published by Mr. Oldham in the report already referred to:—

SECTIONS OF BORE-HOLES AT QUETTA AND BOSTAN.

1. Well at Railway station—

120 feet loess.

20 feet gravel, underlaid by quicksand.

Discharge 20,000 gallons per hour; hydrostatic head 50 feet.

2. Well in Political Agent's compound.

115 feet loess.
8¼ feet shingle with a little artesian water.
2 feet loess.
Gravel, an abundant discharge of water.

3. Well in Loco. Superintendent's compound—

92½ feet loess.
3½ feet gravel with artesian water.

4. Well in Executive Engineer's (Railway) compound—

90¾ feet loess.
10 feet gravel, from which water just flowed at surface.
10 feet loess.
20 feet coarse sand and gravel, with an abundant discharge of water.

5. Well at Gymkhana—

77 feet loess.
10 feet "hard sandy stuff".
8 feet "indurated sandy lumps".
35 feet "clay with nodules".
3 feet quicksand.
12 feet hard clay.
Quicksand with water.

6 Artesian well at Bostan, as determined from specimens preserved—

10—20 feet pale yellow unctuous clay containing fine grains of silica and effervescing freely with acids. LOESS.
20—30 feet the same, but not so fine grained.
30—40 feet finer than 10—20 feet.
40—60 feet very like 20—30 feet.
60—80 feet the same with some pieces of calcareous rock (kankar).
80—90 feet same as 10—60 feet.
100 feet irregular small pebbles of pale grey limestone.
180 feet still in gravel, discharge of water 2,500 gallons per hour.
230 feet or thereabouts, entered as Siwalik clays.

(2) *The Gangetic alluvium.*

Structure of the strata.

Alternating strata of varying coarseness deposited at a gently sloping angle, and becoming generally finer-grained as the distance from the hills increases, are characters common to all alluvial deposits. But endless variation is introduced by differences in horizontal extent, vertical depth and gradient. Thus the conditions which cause artesian flow at Quetta exist to a certain degree in all alluvial plains. Nevertheless the capacity of the reservoirs thus formed must vary greatly according to local conditions. It is natural that the immense extent of land occupied by the Indo-Gangetic alluvium should have attracted a great deal of attention from the point of view of artesian supply, but its capabilities have scarcely been tested : experiments have been so few and so incomplete that its structure is still to a great extent a matter of conjecture. Just as the upper part of the talus skirting the Baluchistan mountains consists of accumulations of boulders continuous with gradually finer gravels that dip under the fine clay deposits of the plains, so does the upper part of the alluvial talus all along the foot of the Himaláyas consist of coarse gravels forming the slope called "bhábar," the lower part of which dips under the soil of the "tarái." Mr. Medlicott argued that the gravel beds of varying degrees of coarseness that are interbedded at various depths with the clay deposits of the alluvium, must be in communication with the "bhábar" zone of gravel : here then, just as in the case of the Quetta plain deposits, leaving aside the difference in proportions, we have the requisite conditions for a very perfect artesian reservoir. Percolation acts freely in the coarse deposits of the gravel zone which absorb a considerable proportion of the rainfall, and the overflow at the upper part of the underground reservoir makes itself evident from the copious springs which issue in the zone along which the gravels dip under the clay deposits of the tarái. This line of springs indicates therefore the altitude of the fountain head of the artesian reservoir, and, by tapping that reservoir in the alluvial plain, at lower altitudes, water may be expected to overflow at the surface. In order to make the conditions of success as favourable as possible, the proposed wells should not be sunk too far south from the Himaláyas, because, with such a low gradient as that which prevails at a distance from the hills, the retarding influence of friction must come conspicuously into play. Along the southern edge of the plains the conditions cannot be regarded as favourable, for all along the low hills that limit the alluvium in that direction, there is no slope of gravel forming an intake area comparable to the "bhábar" of the Himaláyan talus, and in the western portion of the district, in the neighbourhood of the Aravallis, the amount of rainfall is small. As to the underground reservoirs fed by the Himaláyan "bhábar" it is not probable that they stretch right across to the southern boundary of the alluvium. All these probabilities were very distinctly formulated by Mr. Medlicott in discussing the possibilities of the Indo-Gangetic alluvium. It is to the fact of their being situated too far in the midst of the alluvial formation or too near its southern limit, that he attributed the unsatisfactory results of the experiments undertaken in Calcutta in 1836 and at Bhiwani in 1877. One of the consequences of the Umballa boring carried out from 1869 to 1872 was to draw attention to the enormous thickness of the Gangetic alluvium. In order to account for the facts, it became necessary to admit that the floor upon which the Gangetic alluvium was laid down must have been subsiding simultaneously with the deposition of the strata. The depression was probably formed at the same time as the upheaval of the Himaláyas, both phenomena being the outcome of the same set of causes. It may be necessary, therefore, to bore through an enormous thickness of clay-beds similar to those met with in the Umballa boring before striking any permeable sands in communication with the coarse gravels of the "bhábar" zone. The Umballa boring was not continued beyond a depth of 701 feet, and, as an experiment therefore, it was not complete.

The Lucknow boring.

The Lucknow boring performed in the years 1888 to 1890 has further confirmed the fact of the enormous thickness of the alluvium, but it has also established the correctness of Mr. Medlicott's view as to the existence of deep-seated artesian water, for, between the depths of 1,189 and 1,202 feet, a sheet of excellent water was tapped under sufficient pressure to cause it to overflow at the surface. The flow was not abundant, but it is possible that sands bearing a more abundant supply exist lower down. Unfortunately the boring could not be carried deeper than 1,336 feet. It was executed by Mr. Trowbridge, an engineer highly experienced in these matters, who was specially selected for this work by Messrs. Pierce and Co. of New York, one of the leading American firms that have made deep boring a speciality. It had not been anticipated that the boring would have had to be put down to such a depth entirely through unconsolidated alluvial formations. The bore-hole had to be lined throughout its entire depth, and as each size of pipe can be sunk only through a limited depth, the lining had been reduced to 3 inches diameter when it reached a depth of 1,264 feet, the greatest depth to which it was found possible to sink the pipe, although the boring had been commenced with a 12-inch pipe. The following statement contains particulars relative to the lining :—

Size of pipe.	Length.	Depth driven.	Total depth.
1. 12 inches.	408 feet.	408 feet.	408 feet.
2. 10 "	798 "	390 "	798 "
3. 8 "	315 "	100 "	898 "
4. 6 "	1,100 "	202 "	1,100 "
5. 4 "	298 "	89 "	1,189 "
6. 3 "	246 "	77 "	1,264 "

Boring continued to 1,336 feet.

The following information was given by Mr. Trowbridge in his report to the Municipal Board of Lucknow : "From the surface down to about 400 feet, the whole soil appeared to be saturated with water, its natural level being about the same as surface water. From 400 to about 750 feet there was no appearance of water, but at that point, a bed of water-bearing sand was struck, and the water raised to within 13 feet of the surface, which is about 32 feet higher than the Gumti river when at its lowest stage. From 750 feet to 1,220 feet, occasional beds of water-bearing sand were found, which in every instance developed a pressure sufficient to raise the water very nearly, or quite to surface, but evidently of not much volume."

"The last bed of sand found, however, extended from about 1,160 to 1,220 feet, about 13 feet of which—from 1,189 to 1,202—was a live quicksand, and contained water of sufficient pressure and volume to produce a flow over the top of the pipe at 6 feet below the surface, 26 feet above the river, amounting to about 10 gallons a minute —14,400 a day—which proved on analysis to be perfectly pure water. The quantity was not sufficient to be of practical value, and the boring was continued in search of a more abundant supply, and in order to sink the well deeper it was necessary to drive the pipe down, and that cut off and effectually stopped the flow already obtained."

The boring had been undertaken in view of providing a water-supply to the town of Lucknow. On account of the considerable interest arising from its partial success, it was intended to make another trial beginning with a much larger diameter (a 24-inch pipe) by means of which it was hoped that a depth of 2,000 feet would be reached. But it was calculated that even if the experiment were entirely successful, and a copious supply discovered, it would be necessary to bore a number of such wells, perhaps as many as ten, so as to supply the town with sufficient water, and on account of the great expense incurred in boring to such considerable depths, the scheme would have been far more expensive than that of furnishing the town with water from the Gumti river, even with all the additional expense of the plant required for raising the supply, filtering it, etc. Hence the experiment was abandoned.

The record of the Lucknow boring has been published by Mr. Oldham in the publications of the Geological Survey,[1] and is appended below.

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[1] "The deep boring at Lucknow." Rec. Geol. Surv. Ind., Vol. XXIII, pp. 261-266.

Record of the Lucknow Artesian Well.

DESCRIPTION OF SOIL.	Colour.	Thickness of stratum.	Total depth
Made earth, Old Fort embankment	Brown	24	24
Sandy clay	Yellowish brown	17½	41½
Kankar, mixed with clay	Bluish grey	6½	48
Sand and clay, alternate thin layers	Brown	2	50
Quicksand, micaceous	Grey	14	64
Sandy clay	Brown	2	66
Clay, with a little fine sand	Yellow	19	85
Sand, with very little clay	Grey	5	90
Quicksand, fine	Yellow	14	104
Clay	Whitish	5	109
Clay, with scattering kankar nodules	Bluish brown	7	116
Kankar	Bluish grey	6½	116½
Sandy clay	Yellow	1½	118
Kankar and clay, mixed	Bluish grey	1	119
Sandy clay	Yellowish	2	121
Sand, clean	Grey	3	124
Sandy clay	Brown	24	148
Quicksand	Grey	4	152
Silt, fine	Yellowish brown	6	158
Quicksand, fine . . . *water 61 ft.*	Yellowish brown	5	163
Sand, with a little clay	Yellow	6	169
Clay and silt mixed	Yellow	9	178
Clay carrying abundance of nodules	Yellowish (light)	8	186
Sandy clay	Yellow	4	190
Quicksand, very fine . . *water 42 ft.*	Yellowish (light)	6	196

Record of the Lucknow Artesian Well—contd.

DESCRIPTION OF SOIL.	Colour	Thickness of stratum.	Total depth.
Quicksand, coarse	Grey . . .	13	209
Clay	Whitish . .	6	215
Silt, fine	Brown . .	4	219
Sand clay, hard	Brown . .	7	226
Clay and sand, mixed	Yellow . .	7	233
Sand, free and hard	Grey . . .	4	237
Sand, with a little clay, soft	Brown . .	1	238
Sand, free and hard	Grey . . .	1	239
Sand, soft	Grey . . .	2	241
Sand, free and medium hard	Grey . . .	2	242
Sand, quite hard	Grey . . .	2	244
Sand, coarse and nearly as hard as rock . .	Grey . . .	2	246
Sand, medium hard	Grey . . .	10	256
Sand, fine	Brown . .	6	262
Sand, medium hard	Grey . . .	5	267
Sand, soft	Brown . .	4	271
Clay and silt, fine	Light yellow .	4	275
Sand, coarse and very hard	Grey . . .	2	277
Sand, do. medium hard . . .	Grey . . .	2	279
Sand, coarse and hard	Grey . . .	2	281
Sand, coarse, alternate hard and soft layers .	Grey . . .	9	290
Sand, carrying abundance of nodules, hard .	Grey . . .	21	311
Sand and silt, fine	Light yellow .	8	319
Sand, medium hard	Grey . . .	3	322
Sand, very hard, coarse	Grey . . .	9	331

Record of the Lucknow Artesian Well—contd.

DESCRIPTION OF SOIL.	Colour.	Thickness of stratum	Total depth.
Clay and silt, fine	Yellow	7	338
Sand, coarse	Grey	3	341
Sand, coarse *water 24 ft.*	Yellow	17	358
Sand, hard	Grey	2	360
Sand with a little clay, fine	Yellow	5	365
Sand, hard	Grey	4	369
Silt, fine	Brown	4	373
Silt, fine, with occasional nodules	Brown	6	379
Sand, fine and hard	Grey	2	381
Sand, fine and medium hard	Grey	2	383
Silt, fine	Grey	21	404
Silt with abundance of nodules	Grey	4	408
Sandy silt, fine	Yellow	2	410
Clayey silt, fine	Reddish brown	20	430
Clayey silt, fine	Yellow	32	462
Sand, coarse and hard	Grey	1	463
Sand, with a little clay, rather coarse	Grey	7	470
Sand, fine and very hard	Grey	2	472
Sand, fine and medium hard	Brown	8	480
Sand, coarse and medium hard	Brown	9	489
Silt, fine	Brown	2	491
Sand, hard	Grey	2	493
Sand, with a little clay	Grey	9	502
Sand, very hard (like rock)	Grey	1	503
Sand, with occasional very hard thin layers	Grey	7	510

Record of the Lucknow Artesian Well—contd.

DESCRIPTION OF SOIL.	Colour.	Thickness of stratum.	Total depth.
Sand, free and medium hard	Grey	6	516
Sand, fine and soft	Grey	3	519
Sand, medium hard, free	Grey	3	522
Sandy silt, fine	Yellow	14	536
Sand, fine and hard, with a little clay	Grey	12	548
Sand, fine and hard, free	Grey	36	584
Sand, medium hard, free	Yellow	9	593
Clayey silt, very fine	Light yellow	12	605
Sand, medium hard, free	Grey	4	609
Silt, fine and soft	Yellow	13	622
Sand, fine and hard	Brown	2	624
Sand, very hard, like rock	Brown	2	626
Sand, hard and free	Brown	14	640
Sand, medium hard, free	Brown	4	644
Sand, very hard, like rock	Brown	1	645
Sand, medium hard, free	Brown	18	663
Sand, micaceous, with kankar nodules	Yellow	8	671
Sand, fine and medium hard, free	Yellow	4	675
Sand, coarse, with hard layers	Grey	8	683
Sand, coarse and very hard, like rock	Grey	2	685
Sand, extremely hard and fine, like rock	Yellow	5	690
Sand, fine, with abundance of kankar	Brown	10	700
Sand, fine, with very many hard kankar nodules	Brown	10	710
Sand, rather coarse, medium hard, with some kankar	Brown	25	735

Record of the Lucknow Artesian Well—contd.

Description of soil	Colour.	Thickness of stratum.	Total depth.
Sandy silt	Brown . .	15	750
Sand, medium hard, free . *water 13 ft.*	Yellow . .	17	767
Kankar, hard	Bluish grey .	1	768
Sand, with layers of kankar nodules . .	Yellow . .	10	778
Sandy silt, with abundance of mica . .	Grey . . .	5	783
Sand, with occasional kankar nodules *water 9 ft.*	Yellow . .	9	792
Quicksand, with abundance of mica . .	Grey . . .	6	798
Kankar, hard, with a little sand . . .	Light grey . .	6	804
Sand, softish and free	Grey . . .	2	806
Sand, with abundance of nodules . . .	Brown . .	8	814
Silt, very tenaceous	Brown . .	8	822
Kankar, very hard	Bluish grey . .	1	823
Sand, softish, carrying some mica . .	Yellow . .	32	855
Clayey silt, very tenaceous	Yellow . .	7	862
Kankar, hard, with thin streaks of sand .	Bluish grey . .	3	865
Sand, hard and free	Yellow . .	5	870
Sand, medium hard	Yellow . .	7	877
Kankar, hard, with a little sand . . .	Bluish grey . .	3	880
Sand, medium hard, with streaks of silt .	Yellow . .	14	894
Kankar, hard, with a little sand . . .	Bluish grey .	6	900
Sand, fine, medium hard, with a little silt and some nodules	Yellow . .	27	927
Kankar, solid bed, hard as rock . . .	Bluish grey . .	2	929
Sandy silt, very fine	Brown . .	7	936
Limestone, medium hard	Grey . . .	5	941
Sand and limestone, alternate thin layers .	Grey . . .	6	947

Record of the Lucknow Artesian Well - concld.

DESCRIPTION OF SOIL.	Colour.	Thickness of stratum.	Total depth.
Sandy silt, very fine	Yellow . .	13	960
Sand, coarse . . . *water 2 ft.*	Grey . . .	15	975
Sand, coarse, abundance of kankar, some mica.	Grey . . .	15	990
Quicksand, coarse . . *water 5 ft.*	Grey . . .	27	1,017
Sand, coarse, abundance of kankar nodules .	Grey . . .	23	1,040
Sand, coarse and free . . *water 5 ft.*	Grey . . .	15	1,055
Kankar, solid bed, very hard	Bluish grey .	2	1,057
Limestone, soft, commonly called rotten limestone	Grey . . .	7	1,064
Rotten limestone, frequent hard streaks, some nodules	Grey . . .	16	1,080
Limey silt, *i.e.*, limey clay with a little fine sand	Yellowish brown .	27	1,107
Kankar, solid bed very hard	Bluish grey .	2	1,109
Limey silt, with occasional hard nodules . .	Yellow . .	24	1,133
Limestone, medium hard	Grey . . .	2	1,135
Limey silt, alternate hard and soft thin layers .	Yellow . .	3	1,138
Kankar, solid bed, very hard . . .	Bluish grey . .	3	1,141
Limey silt, hard and soft layers some nodules, *water 1½ ft.*	Greyish brown .	7	1,148
Limey silt with occasional hard streaks . .	Yellow . .	13	1,161
Quicksand, coarse, with abundance of mica .	Yellow . .	5	1,168*
Sand, coarse, medium hard, with nodules .	Grey . . .	23	1,189
Quicksand, coarse, with abundance of mica—*water flowed 10 gals. per minute at surface*.	Grey . . .	13	1,202
Sand, coarse, in hard and soft layers . .	Grey . . .	19	1,221
Sand, fine, rather hard, with streaks of silt .	Brown . .	19	1,240
Clayey silt, very fine, compact and uniform .	Greyish brown .	96	1,336

* *Sic.* in original.

The Agra boring.

The Agra boring performed during the years 1884 to 1886 although it failed entirely to prove the existence of any artesian supply of drinkable water, is most interesting from a geological point of view, for it is the only one amongst the borings accomplished in the Indo-Gangetic alluvium that has been carried down to the underlying rock. After traversing 513 feet of alluvial strata, the boring penetrated 132 feet further into the Vindhyan formation, making the total depth 645 feet. Before the commencement of the work Mr. Medlicott was consulted as to the chances of success. He had already advocated Lucknow as a promising locality, but with respect to Agra, he was careful to state that although the existence of artesian water was possible, yet the proximity of the southern boundary of the alluvium rendered success very doubtful: the supply of water from the southern edge cannot be great, and the possible supply from the Himaláyan border cannot very well be relied upon on account of its great distance.

Like the other borings through the Ganges alluvium, the Agra well illustrates the great thickness of that formation. The fact that the alluvial formation extends up to a depth of 513 feet so near to the southern border, shows how rapidly the floor of underlying rock must shelve beneath the accumulation of fluviatile deposits. The bottom of the alluvium at Agra is only 5 feet above sea-level.

The boring was commenced on the 5th of June 1884, and it struck the bottom of the alluvium in May 1885. There remained very little chance of finding a supply of water when once the floor of older rock had been struck, and on the 7th June 1885 the boring was discontinued, agreeably to Mr. Medlicott's recommendation. It was subsequently decided by the Municipality, with the authorization of the Collector and Commissioner, to continue the experiment, and work was resumed on the 21st August of the same year, and the boring continued through rock up to the depth of 645′ 1″ which was reached in July 1886. It was then considered useless to continue the experiment and the work of withdrawing the pipes was commenced. Five different sizes of tubes were used as shown in the following statement :—

	Size of pipe. Inches.	Length. Feet.
1.	9	30
2.	7¾	190
3.	6⅛	367
4.	5¼	470
5.	4¼	490

Unlined boring, 3″ diameter.

The upper end of the 4¼″ pipe was 30 feet below ground level. As its length was 490 feet, it was sunk to a total depth of 520 feet and was lowered 7′ 4″ in the rocky strata, leaving an unlined boring of 125 feet.

While the work of withdrawing the tubes was proceeding, it was noticed that water had risen in the artesian well up to within 36 feet of the mouth of the well, and stood some 12 feet higher than the level of the sub-soil water in the neighbouring wells. Unfortunately it was not observed at what time this rise took place, whether it was when the pipes were withdrawn to the level of some of the sandy layers in the alluvium, or whether the water had been slowly percolating from the Vindhyans. In order to find out how much water was available, the tubes were again sunk at the cost of considerable difficulty, and the bore-hole cleared out, with the object of enabling pumping experiments to be carried out. The work of lowering the tubes was commenced on the 1st of January 1887, and the bore was finally cleared out on the 16th March. Pumping was commenced on the 18th March, at which date "the water was 35 feet 10 inches below the top of the masonry steining. After four hours' continuous pumping it was 84 feet below the top of the well, which gives a fall of 49 feet, and within an hour it rose 51 feet 6 inches, actually 2½ feet higher than it originally was when pumping was first started...........The fall after pumping after the first few days.........appears to have been much less. Pumping was discontinued on the 2nd April, and on the 6th May it was found that the water was 32 feet from the top of the steining, and 16½ feet higher than the water in the well on the opposite side of the road." (Report of the Executive Engineer, dated 18th July 1887.)

At the time of these experiments, the bottom of the 4½" tube was inserted into the Vindhyan rock to a distance of about four feet. The circumstance of the rise of water was brought to the notice of Mr. Medlicott, who was of opinion, however, that the water did not proceed from the Vindhyans: he considered that the pipes were not water-tight, and that the water probably issued from some of the arenaceous strata in the alluvium, perhaps one of those marked 30 or 32 in the list given below. The matter was also referred, at a subsequent date, to Mr. Foote, who concurred in Mr. Medlicott's opinion. Yet, as matters then stood, it was not possible to obtain absolute certainty, which is unfortunate, because this is the only boring in India that has penetrated to any depth through the Vindhyans, and it would be very interesting to obtain some accurate information as to the water-bearing capacity of these rocks, whose stratigraphical structure is in many localities eminently suited to artesian conditions.

The water was so highly charged with salts of magnesia that it was quite unfit for drinking purposes, that in the neighbouring wells being on the contrary quite sweet. As it was found deficient both in quality and in quantity, the experiment was discontinued and the pipes were withdrawn.

The following is the list of strata passed through in the Agra boring.

Record of the Agra boring.

Number of stratum.	Thickness of stratum.		Depth below ground-level.		DESCRIPTION OF STRATA.
	Ft.	in.	Ft.	in.	
1	16	0	16	0	Loam.
2	10	0	26	0	Loamy sand with small kankar.
3	10	0	36	0	Loamy sand.
4	8	0	44	0	Fine sand.
5	19	0	63	0	Loamy clay.
6	27	0	90	0	Loamy sand.
7	20	0	110	0	Kankar and sandy clay.
8	29	0	139	0	White sand and sandstone full of brackish water.
9	5	0	144	0	Small white sandstone and kankar.
10	22	0	166	0	Loamy clay.
11	58	0	224	0	Clay.
12	56	0	280	0	Loamy clay.
13	14	0	294	0	Kankar and clay.
14	2	6	296	6	Kankar.
15	1	6	298	0	Loamy clay.
16	3	6	301	6	Clay.
17	1	0	302	6	Kankar.
18	8	6	311	0	Clay.
19	1	0	312	0	Kankar.
20	15	9	327	0	Clay.
21	11	0	338	0	Loamy sand.
22	7	0	345	0	Red sand and kankar with a little water.

Record of the Agra boring—contd.

Number of stratum.	Thickness of stratum.		Depth below ground-level.		DESCRIPTION OF STRATA.
	Ft.	in.	Ft.	in.	
23	15	0	360	0	Loam.
24	1	6	361	6	Kankar.
25	18	6	380	0	Kankar and clay.
26	10	0	390	0	Loamy clay.
27	4	0	394	0	Clay.
28	2	0	396	0	Kankar.
29	44	0	440	0	Clay.
30	3	9	443	9	Fine sand full of water.
31	23	9	467	6	Loamy clay.
32	3	0	470	6	Fine sand full of water.
33	10	6	481	0	Clay.
34	9	0	490	0	Red sand with pebbles, dry.
35	1	0	491	0	Pebbles and sand.
36	1	0	492	0	Red sand and a little clay.
37	1	0	493	0	Fine sand.
38	1	0	494	0	Mixture of sand, clay and pebbles coloured, kankar and clay.
39	2	0	496	0	Clay and kankar.
40	4	0	500	0	Sand and clay.
41	11	6	511	6	Red clay and sandstone.
42	6	0	517	6	Sandstone.
43	7	6	525	0	Clay and sandstone.

Record of the Agra boring—concld.

Number of stratum.	Thickness of stratum.		Depth below ground level.		DESCRIPTION OF STRATA.
	Ft.	in.	Ft.	in.	
44	26	9	551	9	Sandstone.
45	5	3	557	0	Sandstone, softer.
46	12	0	569	0	Red and white clay with red and white sand with thin layer of sandstone.
47	4	4	573	4	Red and white clay with little sand.
48	5	8	579	0	Sandstone.
49	4	0	583	0	Red clay and soft sandstone.
50	15	9	598	9	Sandstone.
51	2	2	600	11	Red clay and soft sandstone.
52	44	2	645	1	Sandstone with iron interspersed.

The strata numbered 42 to 52 belong to the Vindhyan series.

Boring at Canning in the Sunderbunds.

Another boring sunk in the Gangetic alluvium was the one undertaken in the year 1887 in that part of the delta known as the Sunderbunds. The well was sunk in the hope of getting a supply of fresh water for drinking purposes, as the water in the tidal creeks and rivers is almost all brackish. The site chosen was near the residence of the Agent of the Port Canning and Land Improvement Company, at Canning, about 200 yards from the Mutla river. The experiment is interesting as it shows the possibility of obtaining fresh water from the strata that underlie the brackish water-bearing soil at the surface: a supply of perfectly fresh water was struck at the depth of 173 feet from the surface. The following list of strata is given in the "Indian Engineering" of August 13th, 1887 :—

Record of a boring at Canning in the Sunderbunds.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	DESCRIPTION OF STRATA.
	Feet.	Feet.	
1	6	6	Black earth.
2	4	10	Light grey clay.
3	14	24	Dark grey clay.
4	10	34	Light grey clay.
5	21	55	Black clay, sandy.
6	71	126	Grey sand full of salt water. (This is supposed to be the same stratum of sand found at Diamond Harbour under 28 feet when sinking a well in 1882 in connection with the proposed Docks.)
7	4	130	Dark grey clay.
8	5	135	Green clay with streaks of salt.
9	3	138	Mottled clay, yellow and blue, mixed with broken shingle.
10	2	140	Blue clay.[1]
11	5	145	Yellow clay mixed with broken shingle. This clay is not salt.
12	5	150	Yellow clay with bands of blue and ochre.
13	6	156	Light grey clay, very stiff, mottled with yellow.
14	10	166	Yellow clay, very loamy.
15	7	173	Yellow earth.
16	87	260	Yellow micaceous sand; contains perfectly fresh water which rises to within 8 feet of the surface.

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[1] There is a slight discrepancy between the description given in the text of the "Indian Engineering" and the indications of a section appended to it: the strata 10 and 12 are mutually transposed in the section.

Boring at Chandernagore.

An experimental boring has also been put down at Chandernagore. The boring reached a depth of 242 feet without finding water. The results have been published by Mr. Oldham in the Records of the Geological Survey[1] and are reprinted below. On the subject of this section Mr. Oldham has written the following remarks :—

"The section requires but little comment. The bed No. 13 is evidently the equivalent of the peat bed found near Calcutta at depths of from 30 to 35 feet; No. 32 is peculiar as containing numerous sub-angular fragments of felspar which must have been derived from some exposure of gneiss or granite in the neighbourhood, which has since been covered up by alluvium owing to the subsidence which has taken place in the Gangetic delta; the specimen also contains a fragment of bone, apparently of a turtle, converted into oxide of iron."

Tableau indiquant le nombre et la nature des couches rencontrées pendant le forage du puits artesien de Chandernagor.

	Thickness.	Depth.	Thickness.	Depth.
	Metres.		Feet.	
No. 1. Terre végétale . . .	0·80		2·62	
„ 2. Sable fin micacé d'un blanc sale mêlé de coquilles et de nodules calcaires	1·35	2·15	4·42	70·5
„ 3. Sable fin micacé d'un blanc jaunâtre mêlé légèrement de nodules calcaires . . .	0·45	2·60	1·47	8 52
„ 4. Sable fin micacé d'un jaune rougeâtre	0·25	2·85	·82	9·34
„ 5. Sable fin micacé d'un blanc jaunâtre	0·30	3·15	·98	10·32

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[1] "On a deep Boring at Chandernagore". Rec. Geol. Surv. Ind., Vol. XXVI, pp. 100-102.

Tableau indiquant le nombre et la nature des couches rencontrées pendant le forage du puits artesien de Chandernagor—contd.

	Thickness.	Depth.	Thickness.	Depth.
	Metres.		Feet.	
No. 6. Sable fin micacé d'un gris cendré	0·60	3·75	1·97	12·29
,, 7. Argile sableuse d'un gris foncé	0·35	4·10	1·15	13·44
,, 8. Argile grisâtre mêlée de débris de coquilles et de nodules calcaires	0·65	4·75	2·14	15·58
9. Argile d'un noir grisâtre	2·50	7·25	8·21	23·79
,, 10. Sable fin micacé grisâtre	1·40	8·65	4·59	28·38
,, 11. Argile noire plastique mêlée légèrement de concrétions ferrugineuses	0·54	9·19	1·77	30·15
,, 12. Argile noire stratifiée mêlée legèrement de bois pourris	0·65	9·84	2·13	32·28
,, 13. Tourbe	2·36	12·20	7·75	40·03
,, 14. Argile gris-noir mêlée de toutes petites concrétions ferrugineuses	1·66	13·86	5·44	45·47
,, 15. Argile grise mêlée de petites concrétions calcaires	1·00	14·86	3·28	48·75
,, 16. Argile colorée en jaune et noir mêlée de concrétions calcaires	1·90	16·76	6·23	54·98
,, 17. Argile micacée colorée légèrement en jaune par du carbonate de fer	2·10	18·86	6·90	61·88
,, 18. Argile d'un jaune pale mêlée de nodules calcaires et souillée légèrement de carbonate de fer	2·29	21·15	7·51	69·39
,, 19. Argile bleuâtre tachée en jaune par du carbonate de fer	0·40	21·55	1·31	70·70
,, 20. Argile jaunâtre mêlée de concrétions calcaires	2·25	23·80	7·38	78·08
,, 21. Argile bleuâtre colorée en rouge et en jaune par du péroxyde de fer et de carbonate de fer	0·95	24·75	3·12	81·20

Tableau indequant le nombre et la nature des couches rencontrées pendant le forage du puits artesien de Chandernagor—concld.

	Thickness Metres.	Depth.	Thickness Feet.	Depth.
No. 22. Argile colorée en jaune par du carbonate de fer . . .	8·38	33·13	27·50	108·70
„ 23. Argile sableuse mêlée de graviers	0·55	33·68	1·80	110·50
„ 24. Argile d'un gris pale colorée en jaune par du carbonate de fer et mêlée de nodules ferrugineuses	4·60	38·28	15·10	125·60
„ 25. Argile d'un jaune sale micacée stratifiée colorée en jaune par du carbonate de fer . .	1·15	39·43	3 77	129·37
„ 26. Argile d'un blanc sale micacée .	1·55	40·98	5·09	134·46
„ 27. Argile sableuse micacée souillée d'oxyde de fer . . .	0·55	41·53	1·80	136·26
„ 28. Argile colorée en jaune par du carbonate de fer . . .	1·03	42·56	3 37	139·63
„ 29. Ocre jaune	3·40	45·96	11·16	150·79
„ 30. Sable argileux micacé mêlé de nodules ferrugineuses . .	0·90	46·86	2·95	153 74
„ 31. Sable argileux micacé souillé d'oxyde de fer . . .	1·35	48·21	4·44	158·18
„ 32. Sable moyen et fin micacé mêlé de pétrification cailloux anguleux nodules ferrugineuses .	24·30	72·51	79 81	237·99
„ 33. Sable fin micacé grisâtre . .	1·46	73 97	·79	242 78
„ 34. Sable moyen micacé d'un blanc grisâtre	?	...	[illegible]	...

Chances of success in the Gangetic alluvium.

Thus it appears that none of the borings in the Indo-Gangetic alluvium can be called exactly successful, but the experiments have been so few and so incomplete that it would be premature to predict that a similar fate must attend all future trials. So much can be made out, that the pros-

pects appear very poor along the southern border of the basin. Nearer to the northern border the existence of artesian conditions has been definitely proved by the Lucknow boring, but the water-bearing strata lie probably everywhere at a considerable depth, and data are wanting to form any idea as to the flow that might be expected.

(3) *Other alluvial areas.*

If, from the Indo-Gangetic alluvium, we pass to the smaller alluvial plains in other parts of India, we find that there is very little to be recorded since Mr. Medlicott's general review of the subject.

The expectations raised by the success that attended the sinking of artesian wells at Pondicherry have not been fulfilled in the experiments tried in the other alluvial plains, apparently similarly situated along the east coast of the Peninsula. At Pondicherry itself, a great many wells have been sunk in addition to the four wells described in Mr. Medlicott's Report, and some of these have been very successful, but at Cuddalore, in the southern continuation of the very same alluvial plain, the trial resulted in failure.

Boring experiments at Madras.

A number of experiments have been conducted at Madras and in the neighbourhood of that town, but without much success. At Madras itself, the borings showed that the gneiss occurs at a much smaller depth than was expected, and all hopes of finding an artesian supply had to be abandoned. Already in the year 1832, a boring sunk at the old Custom House had struck the gneiss at the depth of 55 feet.[1] As it was not certain whether this might not have been only a stray boulder, another boring was undertaken in 1885 in the People's Park, but it struck the gneiss at almost exactly the same depth.[2]

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[1] Journ. Royal Asiatic Society, Vol. VIII, p. 248.

[2] A complete collection has not been made of the boring records in the Madras Presidency so as not to defer the publication of the present report, but a number of the more important experiments have been described from information available in the Geological Survey Office.

The following extracts are from a report of the Public Works Department, dated 28th July 1885 : " .... Government accepted an offer from M. Cornet, a French Engineer, to make the experiment of sinking an artesian well at Madras. The maximum depth named for the experiment was 120 metres, or 393 feet; and it was expected that, if the result proved favourable, three months would suffice to complete the work. The approximate estimate of the cost of the well was put down at R15,475.

"The People's Park having been suggested by Dr. King, of the Geological Survey of India, as a locality likely to prove favourable for such an experiment, a site was selected therein, and work was commenced on the 24th March 1885. For a depth of 58 feet the boring was through soil consisting of clay, marl, sand, etc., below which a granitic formation was met with, into which the boring proceeded slowly, the rock being of excessive hardness.

"In order to ascertain whether the rock which had been encountered was a detached boulder, or an extensive underlying bed, a trial boring of small diameter was made at a distance of some 50 yards south of the first site. In this second boring, granite of precisely similar character was reached at the same depth, a result which went to show that the bed was continuous. M. Cornet then proceeded to examine three artesian borings which had been attempted in the vicinity of Madras by private enterprise. From samples of the strata through which these borings had passed, M. Cornet arrived at the conclusion that, from Fort St. George to a distance of six or seven miles north, and a mile or two inland, the underlying strata are everywhere identical and consequently unlikely to yield an artesian supply of water."

Borings in the Kortalayar Plain.

The chances appear to be more promising in the alluvial plain of the Kortalayar river, situated further north. The alluvium occupying this plain has been deposited partly by the Kortalayar; but formerly a larger river also contributed to its formation, the Pálár, which now flows in a different direction. A boring was put down by private enterprise through these strata in the year 1883, near Ennur. A water-bearing stratum was struck at a depth of 65 metres (213 feet). There does not appear to exist any detailed record of the boring: it reached a depth of 214 feet in September 1884, but by that time it had proceeded beyond the alluvium and had penetrated the underlying tertiary and jurassic beds.

The Karani boring.

In June 1886, a boring was commenced at Government expense at Karani in the Kortalayar valley. The result was disappointing as only two sheets of water were met with at depths of ten and forty feet, neither of which were very abundant. The boring was continued to a depth of 442 feet without striking any other supply. The list of strata encountered is given below. According to Mr. Foote it is doubtful whether all these strata belong to the recent alluvial deposits of the Kortalayar and Pálár. Just as in the experiment at Ennur, it is possible that the lower part of the boring has been sunk through rocks older than the alluvial, in the present case the "Cuddalore sandstone" of tertiary (or pleistocene) age.

Section of the Karani boring.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	DESCRIPTION OF STRATA.
	Feet.	Feet.	
1	4·50	4·50	Sandy vegetable mould, yellowish, then black clay with a small portion of sand.
2	2·50	7·00	Fine yellowish sand with a few pieces of kankar.
3	4·00	11·00	Greyish sand with a little clay and pieces of kankar. Water sheet at 10 feet.
4	2·00	13·00	Fine yellowish sand with some kankar.

Section of the Karani boring—contd.

Number of stratum.	Thickness of stratum.	Depth below ground-level	DESCRIPTION OF STRATA.
	Feet.	Feet.	
5	12·00	25·00	Sandy clay yellowish brown mixed with some blue clay nodules and pieces of kankar; clay passing to whitish yellow mixed with sand.
6	6·00	31·00	Yellow and white clay with kankar in small quantity.
7	6·00	37·00	Yellow-brown clay with more kankar, passing to conglomerate with patches of green and white clay, and fragments of laterite transported by water.
8	4·00	41·00	Very hard yellow clay, whitish when dry; at 38 feet, pieces of white coral passing to reddish-brown.
9	2·50	43·50	Yellowish coarse sand mixed with clay.
10	6·12	49·62	Coarse river sand mixed with clay. The strata 9 and 10 contain water under pressure which rose to within 3′ 3″ of the ground-level in November 1886. In March 1887, the surface of the water was 6′ 9″ below ground-level.
11	2·03	51·65	Fine sand mixed with yellow clay.
12	1·75	53·40	White clay with portions of yellow clay like laterite.
13	5·25	58·65	Very hard sandy yellow clay with water-worn fragments of gneiss.
14	12·00	70·65	Similar stratum containing fine sand mixed with clay, coarse river sand, and a few pebbles.
15	12·00	82·65	Very stiff yellow clay mixed with red and grey clay in patches and layers, containing water-worn fragments of laterite. Becomes arenaceous at 80 ft.
16	0·75	83·40	Bed of limestone.
17	3·00	86·40	Yellow clay mixed with some white clay and layers of grit.

Section of the Karanj boring—contd.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	DESCRIPTION OF STRATA.
	Feet.	Feet.	
18	1·75	88·15	Some yellow clay, mixed with red clay.
19	5·50	93·65	Clay resembling laterite, containing pebbles and sand derived from the primary rocks.
20	7·00	100·65	Hard yellow clay mixed with sand and fragments of gneiss; then hard greyish clay mixed with yellowish clay. At 99 feet, more grey clay passing to blue clay.
21	3·00	103·65	Grey clay traversed by blue clay.
22	3·00	106·65	Blue clay mixed with some yellow clay.
23	5·18	111·83	Stiff yellow clay.
24	1·28	113·11	Stiff yellow clay traversed by blue clay.
25	45·77	158·88	Very hard indurated blue clay with a few layers of grit.
26	2·30	161·18	Greyish limestone, the lower part of which is very hard.
27	18·92	180·10	Blue clay and layers of grit. The lower part of the stratum contains iron-pyrites.
28	10·86	190·96	Fine blackish grey sand with iron pyrites, mixed with very hard indurated blue clay, containing sometimes layers of grit and limestone.
29	1·00	191·96	Very hard greyish limestone.
30	9·04	201·00	Fine blackish grey sand with iron pyrites, mixed with very hard indurated blue clay, containing sometimes layers of grit and limestone.
31	6·00	207·00	Fine blackish blue stiff clay; lower part greyish.
32	1·00	208·00	Very hard grey limestone.
33	2·50	210·50	Fine indurated greyish clay, with a little sand.

Section of the Karani boring—contd.

Number of stratum.	Thickness of stratum	Depth below ground level	DESCRIPTION OF STRATA.
	Feet.	Feet.	
34	6·00	216·50	Very hard black clay; lower part containing layers of grit.
35	6·25	222·75	Very hard grey limestone.
36	7·00	229·75	Grey sand with indurated clay.
37	13·00	242·75	Indurated grey sand mixed with clay, pieces of shell and decayed leaves, and nodules of carbonate of lime.
38	7·00	249·75	Indurated grey sand containing clay and fragments of shells.
39	4·00	253·75	Indurated grey sand mixed with clay.
40	4·00	257·75	Indurated grey sandy clay passing into conglomerate containing fragments of kankar.
41	54·25	312·00	Coarse sand with greyish clay.
42	5·00	317·00	Black clay.
43	0·75	317·75	Grey limestone.
44	2·25	320·00	Black clay.
45	1·00	321·00	Grey limestone.
46	27·00	348·00	Black clay.
47	1·00	349·00	Grey limestone.
48	2·00	351·00	Grey sand mixed with clay.
49	4·00	355·00	Black clay.
50	12·00	367·00	Hard grey clay.
51	2·00	369·00	Grey limestone.
52	0·50	369·50	Layers of grit.
53	0·75	370·25	Grey sandy clay.

Section of the Karani boring—concld.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	DESCRIPTION OF STRATA.
	Feet.	Feet.	
54	37·75	408·00	Black clay; upper part contains fragments of decayed wood and broken shells.
55	4·00	412·00	Grey sand mixed with clay.
56	4·00	416·00	Indurated black clay.
57	2·00	418·00	Grey sand mixed with a little clay.
58	1·00	419·00	Indurated black clay.
59	1·00	420·00	Grey sand with clay.
60	21·00	441·00	Grey clay with sand.
61	1·00	442·00	Limestone.

The altitude of the ground at the mouth of the well is 71 feet above sea-level.

Coconada boring.

A successful experiment has been made lately at Coconada, on the sea-coast in the northern part of the delta of the Godavári.

But here, in all probability, the greatest part of the boring is not through alluvium, but through the "Rajahmundry beds," a local facies of the Cuddalore sandstones. An abundant supply of water was struck at a depth of 295 feet, the water overflowing at a height of about one foot and a half above the surface of the ground. The "Rajahmundry beds" consist of alternating layers of sandstone and clay. They outcrop over a considerable area to the north-west of Coconada, and as they dip under the alluvium at a low angle in a south-south-east direction towards the sea-coast, they ought to be very favourably situated with respect to artesian conditions.

The following list of the strata met with has been kindly communicated by the Engineer-in-Chief of the East Coast Railway:—

Section of Artesian Well boring at Coconada Town.

Number of stratum.	Thickness of stratum.		Total depth from top of spoil bank.		DESCRIPTION OF STRATA.
	Feet.	In.	Feet.	In.	
1	10	0	10	0	Sand.
2	20	0	30	0	Clay.
3	80	0	110	0	Clay and a few pebbles, then clay and sand.
4	30	0	140	0	Clay.
5	10	0	150	0	Sand.
6	70	0	220	0	Clay, then decomposed rock.
7	10	0	230	0	Sand and soft sandstone.
8	48	0	278	0	Clay.
9	1	0	279	0	Decomposed rock and coarse sand.
10	1	0	280	0	Disintegrated rock.
11	9	0	289	0	Coarse sand.
12	1	0	290	0	Sand conglomerate.
13	1	9	291	9	Sand.
14	0	3	292	0	Soft sandstone.
15	3	0	295	0	Sand.

Tank spoil bank level about 3 feet above ground-level. Water level in pipe at a depth of 1′ 6″. Diameter of bore-hole, 8½ in. Total depth of lining 290 feet.

An experimental boring is being conducted at present in another part of the alluvial deposits of the Godávari at Ellore. But as it seems certain that it is at present in Gondwana rocks, it will be mentioned again in connection with other experiments carried out in rocks of that class.

Karikal boring.

A trial was also made in 1881-82 at Karikal, a town whose geographical and geological situation resembles that of Pondicherry. The undertaking did not meet with the same success as at Pondicherry although two artesian sheets were struck, the first one at a depth of 346 feet, which rose to within 4 inches of the surface, and a second one at a depth of 347 feet, which overflowed. The hydrostatic head of the latter was 6½ feet above the level of the ground, but its delivery was only 22 gallons a minute. A copy of the boring record communicated by the French Government Engineer is herewith appended. Like the Chandernagore boring record, it is printed in the original language with only the addition of the measurements in feet:—

Coupe géologique du Puits Artésien de Karikel.

Number of stratum.	Thickness of stratum in metres.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	DESCRIPTION OF STRATA.
1	2·00	2·00	6·56	6·5	Terrain naturel. Sable gris-noir terreux.
2	0·45	2·45	1·47	8·0	Sable gris-noir terreux avec mélange de sable jaune-brun fin.
3	0·79	3·24	2·59	10·6	Sable gris-noir argileux.
4	1·04	4·28	3·41	14·0	Argile noire plastique avec oxyde de fer et mêlée de sable blanc, gris et jaune-brun.
5	1·02	5·30	3·34	17·3	Argine jaune-brun mêlée de sable.
6	1·40	6·70	4·59	21·9	Sable fin jaune-brun avec petits graviers.
7	0·75	7·45	2·46	24·4	Sable moyen jaunâtre avec graviers et grès ferrugineux.

Coupe géologique du Puits Artésien de Karikel—contd.

Number of stratum.	Thickness of stratum in metres.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground level in feet.	DESCRIPTION OF STRATA.
8	1·05	8·50	3·44	27·8	Sable fin micacé jaune pâle.
9	1·10	9·60	3·60	31·4	Argile grise avec mélange de terre de soude.
10	3·15	12·75	10·33	41·8	Argile brune mêlée de sable.
11	1·10	13·85	3·60	45·4	Argile sableuse rougeâtre.
12	1·45	15·30	4·75	50·1	Sable argileux jaunâtre avec grès ferrugineux.
13	0·36	15·66	1·18	51·3	Sable gros argileux jaune-pâle avec petits graviers.
14	0·30	15·96	0·98	52·3	Sable fin micacé fluide.
15	1·74	17·70	5·70	58·0	Argile brune sableuse.
16	3·15	20·85	10·33	68·4	Sable jaune clair fin.
17	0·57	21·42	1·87	70·2	Sable gros argileux gris-clair avec graviers et choukan.
18	0·53	21·95	1·73	72·0	Terre de sonde fluide.
19	0·85	22·80	2·78	74·7	Sable moyen gris avec terre de soude, mottes d'argile irisée et choukan.
20	2·70	25·50	8·85	83·6	Argile brune sableuse irisée avec choukan.
21	4·45	29·95	14·60	98·2	Argile irisée mêlée de terre de soude.
22	0·80	30·75	2·62	100·8	Argile irisée mêlée de sable fin micacé.
23	0·65	31·40	2·13	103·0	Argile gris-noire avec agglomérats.
24	0·45	31·85	1·47	104·4	Argile brune sableuse avec agglomérats.
25	0·30	32·15	0·98	105·4	Argile schisteuse irisée.

Coupe géologique du Puits Artésien de Karikel—contd.

Number of stratum.	Thickness of stratum in feet.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	DESCRIPTION OF STRATA.
26	2·25	34·40	7·38	112·8	Sable fin micacé jaune pâle avec agglomérats.
27	13·00	47·40	42·65	155·5	Sable fin jaune-brune avec grès ferrugineux, cailloux et graviers.
28	2·20	49·60	7·21	162·7	Argile brune mêlée de sable fin micacé.
29	0·80	50·40	2·62	165·3	Sable moyen jaune pâle avec petit graviers.
30	2·10	52·50	6·88	172·2	Argile brune sableuse.
31	0·80	53·30	2·62	174·8	Argile gris-noire marbrée avec agglomérats.
32	3·15	56·45	10·33	185·1	Argile sableuse irisée avec agglomérats.
33	0·23	56·68	0·75	185·9	Sable rougeâtre argileux, avec cailloux, graviers, gres ferrugineux et débris de coquilles.
34	0·55	57·23	1·80	187·7	Agglomération.
35	0·35	57·58	1·14	188·8	Sable argileux jaune rougeâtre avec petits graviers et cailloux.
36	1·67	59·25	5·47	194·3	Sable moyen sali d'argile jaunâtre et mêlé de petits graviers.
37	3·00	62·25	9·84	204·1	Argile irisée compacte avec rognons d'agglomération.
38	1·25	63·50	4·10	208·3	Argile irisée mêlée de sable fin et avec agglomération.
39	0·65	64·15	2·13	210·4	Argile compacte irisée avec rognons d'agglomérats.

Coupe géologique du Puits Artésien de Karikal—contd.

Number of stratum.	Thickness of stratum in metres.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	DESCRIPTION OF STRATA.
40	0·75	64·90	2·46	212·9	Argile gris-cendrée irisée avec rognons d'agglomérats.
41	1·05	65·95	3·44	216·3	Argile jaune-rougeâtre irisée mêlée de sable et de graviers et souillée d'oxyde de fer.
42	0·10	66·05	0·32	216·6	Agglomération.
43	0·40	66·45	1·31	217·9	Sable fin jaune pâle avec graviers et débris de coquilles.
44	0·25	66·70	8·82	218·8	Agglomération.
45	0·50	67·20	1·64	220·4	Sable moyen rousseâtre sali d'argile
46	0·55	67·75	1·80	222·2	Argile sableuse irisée avec graviers et agglomérats.
47	0·40	68·15	1·31	223·5	Argile sablonneuse irisée.
48	1·05	69·20	3·44	227·0	Sable fin souillé d'ocre-jaune et mêlé de débris de coquilles.
49	0·10	69·30	0·32	227·3	Agglomération.
50	0·70	70·00	2·29	229·6	Sable moyen jaunâtre sali d'argile et mêlé de graviers.
51	0·40	70·40	1·31	230·9	Agglomération.
52	4·18	74·58	13·71	244·6	Sable moyen jaunâtre souillé d'argile et mêlé de petits graviers, de débris de coquilles et de rognons d'agglomérats.
53	0·62	75·20	2·03	276·7	Agglomération.
54	1·35	76·55	4·42	251·1	Sable fin jaunâtre souillé d'argile.

Coupe géologique du Puits Artésien de Karikel—concld.

Number of stratum.	Thickness of stratum in feet.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in teet.	DESCRIPTION OF STRATA.
55	1·15	77·70	3·77	254·9	Sable moyen jaunâtre argileux avec débris de coquilles et rognons d'agglomération.
56	6 75	84·45	22·14	277·0	Argile noire plastique mêlée de coquilles et d'argile blanche.
57	0·80	85·25	2·62	279·6	Sable argileux noirâtre avec petits graviers et cailloux et traces de coquilles.
58	0·45	85·70	1·47	281·1	Agglomération pierreuse de couleur gris-âtre.
59	3·67	89·37	12·04	293·1	Sable argileux moyen, de couleur gris-âtre avec mélange de cailloux, de graviers et de coquilles.
60	0·20	89·57	0·65	293·8	Agglomération.
61	0·63	90·20	2·06	295·9	Argile gris-noire claire mêlée de graviers, cailloux et débris de coquilles.
62	1·50	91·70	4·92	300·8	Argile gris-noire mêlée de sable fin.
63	9·86	101·56	32·34	333·1	Argile grise mêlée de sable de graviers, cailloux, boispourris, et rognons d'agglomération.
64	0·30	101·86	0·98	334·1	Agglomération.
65	3·35	105·21	11·09	345·2	Sable gris-noir argileux avec cailloux, graviers et débris de coquilles.
66	0·30	105·51	0·98	346·1	Agglomération.
67	0·20	105·71	0·65	346·8	Sable gris fin pur.
68	0·10	105·81	0·32	347·1	Agglomération.
69	1·59	107·40	5·21	352·3	Sable gros gris pur avec graviers cailloux.

Wells at Rangoon.

A considerable portion of Burmah is occupied by alluvium, and it is probable that there are places where the conditions are favourable to artesian action. The "tube-wells" sunk in the alluvium of Rangoon appear to be partly artesian in their characters, although in none of them does the water overflow. They are situated close to the banks of the Rangoon river and the Poozoondoung creek, and as the water in the deep-seated water-bearing sands appears to flow very freely from the direction of the higher ground round the Shway Dagon pagoda hill towards the river banks, the pressure is not sufficient to cause any overflow in such a situation: the water does not rise to within less than 5 to 11 feet from the surface. Mr. Oldham, who has written an account[1] on the subject of these wells from which the present information is gathered, was of opinion that flowing wells might be obtained further inland, though the rise of the ground is so slight that no great increase of the pressure can be expected. As to any scheme of supplying the town with water from this source, Mr. Oldham pointed out that the yield of the wells is not very large (the wells then in existence gave amounts varying from 2,500 to 70,000 gallons a day), and that, owing to irregularities common in all alluvial formations, a certain number of the proposed wells are sure to be failures: hence "a large number of wells will therefore have to be sunk if the requisite supply of water is to be obtained, and it seems probable that, when the estimates are made out, it will be found that the cost will be nearly if not quite as great as for the construction of a storage reservoir, while the cost of maintenance and uncertainty of success will be much greater."

Some of the wells go down to depths of as much as 320 feet. The strata encountered belonging to the "newer alluvium" above, and the "older alluvium" below, as defined by Mr. Theobald in his survey of the geology of the district. The fact that below a certain point on the banks of both the Rangoon river and the Poozoondoung creek, all the wells contain more or less brackish water shows that there is very free underground communication, and that "there is a continuous outflow from the outcrop of the gravels to the sea," the permeable sands not being perfectly enclosed by watertight strata.

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[1] Note on the alluvial deposits and subterranean water-supply of Rangoon. Rec. Geol. Surv. Ind., Vol. XXVI, pp. 64-70.

Mr. Oldham gives the following description of the method by which the wells were sunk :—" they are cased with iron piping of from 2½" to 4" internal diameter, which was sunk by the simple process of forcing a stream of water down a smaller tube of from 1" to 2" bore, inserted in the centre of the outer casing. The stream of water ascending the annular space between the two tubes carried with it the material washed from the bottom of the bore, and so enabled the two tubes to be sunk simultaneously ; when the well was completed, the inner tube was withdrawn and a pump attached to the outer one. This process appears to be simple, inexpensive, expeditious, and effectual, though of course only applicable in soft and not too coarse grained deposits, but it has an effect on the stuff washed out that must be allowed for. The stream of water which is sufficient to wash away fine clays or sands, would be insufficient to bring up coarse grit and small pebbles to the surface. Consequently if pebbles are mixed with fine sand or clayey matter, the stream, which has sufficient power to bring the pebbles to the surface, will wash away all the finer matter, and so what would seem to be a clean gravel, to judge from the washed material brought up, might really be a mixture of pebbles and clayey sand, of very little value as a source of water. "

With respect to the boring records appended below, Mr. Oldham makes the following remarks :—

" Most of these sections have been preserved in glass fronted boxes, in which the different layers are arranged one above the other. In some cases this has been done to scale, and there was no difficulty in determining the depths and thicknesses, in others no fixed scale was followed, and the depths are indicated by paper slips affixed to the glass, a much inferior plan, for when, as has sometimes happened, any of these labels have peeled off, it is impossible to determine the true thickness of some of the layers. Where I have not seen the specimens, or none have been preserved, the section is given by repute. The term grit is used to indicate a texture intermediate between that of sand and of gravel, the limits of size of the individual grains may be taken as $\frac{1}{32}$ and $\frac{1}{8}$ inch. The horizontal line indicates the base of the newer alluvium."

Detailed sections of borings.

No 1. Mohr Brothers.

There are two wells, the section of the deepest is—

0—109 ft. fine grey clayey silt.
109—136 „ fine grey sand.
136—180 „ grey clayey silt.
180—190 „ yellowish sand (silt of the newer alluvium mixed with sand grains of the older).
———
190—210 ft. sand.
210—220 „ fine gravel ranging to ¼" diameter.
220—270 „ coarser gravel, some pebbles as much as an inch in diameter.
below 270 feet, yellow sand again.

No. 2. Bulloch Brothers & Co.

One well, section said to be—

0— 90 ft. clay.
90— 96 „ sand.
96—220 „ clay.
220—240 „ yellow sand and gravel.

No. 3. Diekmann Barckhausen & Co.

One well, 242 feet deep. No record.

No. 4. Steel Brothers & Co. Upper mill.

Two wells, 50 feet apart. There is a distinct difference in the water of the two. One contains a small proportion of oily matter, probably petroleum, which floats on the surface of the water. Section—

0— 30 ft. fine brown silt.
30— 40 „ dirty yellowish sand.

40— 60 ft.	grey sandy silt.
60— 70 ,,	fine sand.
70— 80 ,,	yellowish sand.

80— 85 ft.	fine grey sand.
85—100 ,,	brown earth.
100— ,,	yellow sand.
—175 ,,	coarse grit and sand.
175—190 ,,	coarse grit.
190—210 ,,	fine gravel.
210—238 ,,	gravel ranging to ½ inch in diameter.

No. 5. Steel Brothers & Co. Middle mill. Section—

0— 85 ft.	grey clayey silt.
85— 99 ,,	fine sand.
99—100 ,,	grey sandy silt.
100—118 ,,	fine grey sand.
118—122 ,,	grey sand with yellowish grains.
122—130 ,,	fine grey silt.

130—145 ft.	clean sand.
145—150 ,,	coarse grit with some fragments ranging to ½ inch in diameter.
150—155 ,,	grey silt.
155—160 ,,	coarse sand mixed with small ferruginous concretions
160—176 ,,	fine clean sand.
176—180 ,,	fine reddish sand.
180—190 ,,	coarse sand.
190—195 ,,	medium grained yellow sand.
195—198 ,,	grit.
198—203 ,,	coarse grit with some larger fragments.
203—229 ,,	gravel ranging to ¼ inch.

No. 6. Kruger & Co.

Section lost. At about 250 feet a large number of shells in a very good state of preservation and in some cases quite fresh looking were brought up. The forms are all marine littoral, comprising the genera *Cardium*, *Arca*, *Venus*, *Solen*, besides fragments of polyzoa. The species appear to be living ones.

No. 9. Zaretskey Book & Co. Section—

0— 30 ft. grey silt.
30— 42 ,, fine brownish sand.
42— 55 ,, small ferruginous concretions.
55—125 ,, grey clayey silt.
123—217 ,, grey sand.

217—220 ft. sub-angular gravel.
220—249 ,, fine pale buff sand.
249—254 ,, pale yellow sand.
254—257 ,, coarse grit and sand.
257—289 ,, pale yellow sand.
289— ,, coarse grit and sand.

" Through the courtesy of the proprietors this well was pumped for me with an open mouth. It was found that the well gave 1,200 gallons an hour with a lowering of the surface level to 8 feet. "

No. 7. Steel Brothers & Co. Lower mill.

No record except that the water was brackish.

No. 8. Rowett & Co.

Two wells were sunk, both were failures. No further record.

No. 10. Bulloch Brothers & Co. Section—

0— 25 ft. fine clayey silt.
25— 52 ,, fine sandy silt.
52— 70 ,, fine grey sand.
70—108 ,, silt.
108—118 ,, fine grey sand.
118—170 ,, alterations of more or less sandy and clayey silt.
170—256 ,, grey sand of various shades.
256—265 ,, grey sand with some yellow grains.

265—275 ft. yellow sand.
275—282 ,, grit.
282—302 ,, sharp yellow sand.
302—320 ,, gravel ranging to ½ inch.

No. 11. Arracan Co.

Two wells sunk to 240 and 245 feet; water bad. No further record.

No. 12. Arracan Co.

One well of 140 feet. Water not good. No further record.

No. 13. Victoria Oil works. Section—

0— 20 ft. grey clayey silt
20— 80 „ fine grey sand.

80—100 ft. yellowish sand.
100—120 „ fine sub-angular gravel.
120—134 „ pepper and salt grey sand
134—155 „ sand with small pebbles
155—190 „ sand.
190—215 „ small sub angular gravel
215-218 „ sand.
218—230 „ gravel mostly small, imperfectly rounded, with some fragments of ¾ inch across.
230—236 „ fine sand
236—240 „ gravel as before.
240—250 „ fine grey sandy silt.
250—257 „ coarse grit.
257—265 „ fine white sand.
265—273 „ sand and grit.
273—276 „ white sand.
276—279 „ white grit.
279— „ gravel, ¼ to ¾ inch.

No. 14. Irrawady Flotilla Co.

One well of 170 feet, water brackish. No further records.

No. 15. McGregor Brothers & Co. Section said to be—

0— 50 ft. blue clay.
50— 62 „ red clay.
62— 96 „ sand.
96—224 „ gravel, then sand and thin beds of white clay
224—228 „ gravel.

No. 16. Foucar Brothers & Co.

No record.

No. 17. Bulloch Brothers & Co. Section—

0— 30 ft. brownish silt.
30— 43 „ grey silt.

43— 62 ft. brick red clayey matter (soft laterite?).
62— 68 „ fine buff sand.
68— 75 „ fine pale greyish sand.
75—110 „ yellow sand.
110—130 „ clean sharp sand.
130—148 „ grit.
148—161 „ yellowish sharp sand.
161—165 „ fine brown sand.
165—171 „ coarse sand.
171—180 „ coarse sub-angular grit.
180—185 „ gravel up to an inch in diameter.

No. 18. Heatherington Gray & Co.

One well of 250 ft. Water bad ; no record.

No. 19. Mohr Brothers & Co. Section—

0— ft. fine grey silt.
—196 „ grey silt mixed with grains of reddish sand.

196— ft. grey sand with some small pebbles.
—210 „ clean yellow sand.
210—215 „ coarse sand.
215— „ small gravel.
—224 „ coarse grit.
224—230 „ fine grit and coarse sand.
230—242 „ sub-angular gravel ranging to ¼ inch.

Boring at Akyab.

An experimental well was sunk at Akyab in 1889-1890. But it is difficult to make out how far the work proceeded through alluvium, or whether it entered the underlying tertiary rocks. The locality was visited in 1897 by the late Mr. Grimes, who wrote the following particulars on this subject : "In the years 1889-90, at the Arracan Company's Upper Mill, on the north side of the town of Akyab, a well was bored to a depth of 421 feet, for the purpose of obtaining water, but without any success. The only record of this boring which I could obtain was in a letter from the Arracan Company to the Akyab Municipal Commissioners, in which they write that at 421 feet they reached a stiff clay and could make no further progress, and that long before they reached the clay they went through several layers of sand and gravel, but there was no sign of water anywhere. This is very indefinite as it does not show how much of this depth was bored in the alluvial beds or whether it was even entirely in the alluvium. Wells sunk close to the ridge of rocks get down through the alluvium to the underlying rock at a very moderate depth, but there is evidence to show that the thickness of the recent deposits increases as one gets away from this ridge, and the increase is possibly very rapid."

(4) *Gujárát.*

A large portion of Gujárát is covered with alluvium, but not to any depth comparable with that of the Indo-Gangetic plain. The subject of artesian wells has received a certain amount of attention in that province because irrigation is needed to supplement occasional deficiency of rainfall, and also on account of the fact that in many places the water of the wells is hard and brackish. Although the depth of the alluvium is inconsiderable, very little is known concerning the older rocks underlying it. So far as can be made out, the Gulf of Cambay seems to occupy a shallow basin of disturbance; the various strata, both to the east and west, dipping at low angles under the alluvium. The structure therefore is favourable to the formation of an artesian reservoir, provided that some of the strata have a capacity for transmitting water. In all probability the rocks underlying the alluvium are basaltic strata of the "Deccan trap" overlaid by tertiary strata If, as is not improbable, the lowest strata of the tertiaries are coarse gravel beds resting upon the surface of the volcanic layers, thi circumstance combined with the

Structure in the neighbourhood of the Gulf of Cambay.

abundance of overlying impermeable clays that form such a large proportion of the tertiaries, would give rise to conditions eminently suited to artesian action. So far, however, no borings have penetrated to such a depth. The boring sunk at Gogah by Lieutenant Fulljames in 1836-1839, to a depth of 354 feet 9 inches, mention of which is made in Mr. Medlicott's Report, still remains the most important attempt, and it never reached the base of the tertiaries.

Salt-bearing strata.

Some of the tertiary strata contain strings and crystals of rock-salt within their layers, and it seems to be owing to this circumstance that the wells in some parts of Gujárát contain brackish water. The behaviour of the wells varies according to the depth at which these salt-bearing strata lie below the surface. It may happen that the well, when first sunk, contains fresh water from surface layers unaffected by the brackish water lower down; but if the demand upon the water-supply in the well increases beyond a certain extent, the brackish water may percolate from below. This is particularly liable to occur in seasons of exceptional dryness when the general level of sub-soil water has been lowered, and the communication thus established with the deeper layers of contaminated water may cause the wells to become permanently deteriorated.

Fresh water-supply tapped by borings of moderate depth.

In places thus situated, a supply of perfectly fresh water has sometimes been tapped by sinking a pipe from the bottom of the well, until it penetrated through some layer of impermeable clay. Separated by this impermeable bed from the upper layer of saline water, the supply thus obtained is artesian in the strict sense of the term, although the water may not rise higher than the level of ordinary ground-water.

Experiments at Naosari.

Some very successful attempts of this class have been made by Mr. G. W. Tata at Naosari, an abundant supply of fresh water being obtained at a depth of about 150 feet.

Report by Mr. Griesbach.

The country was visited by the Director of the Geological Survey, Mr. Griesbach, at the commencement of the year, and the following remarks are extracted from his notes.

Notes on the chances of finding Artesian water in Gujárát.

"(1) Gujárát with the adjoining districts, Cutch, Kathiawar, Mahi Kantha and the Panch Mahals may, for the purposes of the water inquiry, be roughly divided into three well-defined areas, which differ stucturally from one another. There are (*a*) the hilly tracts which include the Mahi Kantha and Panch Mahals; (*b*) the Cutch and Kathiawar States, which fringe Gujárát along the south-west; and (*c*) the flat country between the hill tracts which is formed by the drainage running into the Gulfs of Cutch and of Cambay.

(2) The hilly tracts of the Mahi Kantha and Panch Mahals consist chiefly of older rocks, both schistose and crystalline, both much disturbed. Several of the valleys within this area are filled with recent deposits, but there is no evidence to show that a search for artesian water will meet with any success within these deposits.

(3) The areas of Cutch and Kathiawar which form the south-western fringe of Gujárát are chiefly built up of younger sedimentary strata (both cretaceous and tertiary beds) which are associated with the so-called Deccan trap, and I think it is extremely unlikely that within this area artesian conditions will be met with, although even so much cannot be absolutely insisted upon, but the general geological structure is certainly not promising, and I would not advocate the outlay of money on a systematic search for such a water-supply, especially as water may in most instances be found within reasonable depths by digging ordinary wells.

(4) It appears to me that the only part of the northern division of the Bombay Presidency, within which a search for artesian water

might be successful, is Gujárát proper, that is the flat country inclosed by the Mahi Kantha on one side and Kathiawar on the other. It appears to be entirely covered by widespread alluvial deposits, and very little is known of the underground geological conditions, but a few exposures in quarries and wells afford some information, which is sufficient to permit forming a favourable opinion on the chances of meeting with deep-seated supplies of water if borings were undertaken.

The few exposures of underground structure which I have seen seem to indicate that the alluvial deposits cover up a series of beds of upper jurassic or cretaceous age, consisting chiefly of sandstones and shales, and overlaid by tertiary clays, shales and limestones, the whole of which sequence of beds rests upon the old palæozoic rocks of the so-called 'Aravalli type.'

(5) The evidence in support of this supposition is somewhat meagre; besides the geological surveys of Kathiawar and Baroda, we possess surveys of the alluvium of parts of the Ahmedabad district, whilst important evidence is afforded by quarries and newly-constructed wells near Wadhwan.

(6) I have satisfied myself that we have at least two distinct water-levels within this area. The lower one is found wherever the cretaceous marls and impure limestones, which may be seen along the boundary of Gujárát and Kathiawar, are pierced down to the underlying coarse brown sandstone of cretaceous or upper jurassic age. This may be clearly observed in all the quarries near Wadhwan itself.

The upper water-level is found in the tertiary (probable upper eocene) concretionary limestone which seems to overlie the cretaceous deposits of Wadhwan unconformably (much of the so-called kankar beds appear to be the same concretionary limestone of the upper eocene which may easily be mistaken for the genuine kankar deposits of the alluvium).

If a bore-hole were sunk 7 or 8 miles north-east of Wadhwan, for instance, it would probably encounter the following series of beds in succeeding order:—

1. Alluvium, probably 10 to 20 feet.
2. Tertiary limestones and marls,—some 40 to 60 feet.

:

Upper Water-level.

:

3. Unknown strata, probably of tertiary age and of unknown thickness.

:

4. Upper cretaceous limestones and marls.
5. Brown sandstone, cretaceous or jurassic.

Lower Water-level.

:

6. Unknown strata below.

It will be seen therefore that water would certainly be obtained by boring, and it may be that by driving the boring down to the lower water-level indicated above, artesian conditions will be encountered. The proposition appears to me hopeful, and I would suggest that such a bore-hole be constructed of at least 1,000 ft. depth in the neighbourhood, say, 7 miles north-east of Wadhwan.

(8) Experiments made in former years, and the experience gained in well sinking, have proved that water may be obtained almost everywhere in Gujárát,—although in varying depths. It appears also, that much of the water-supply from wells is more or less brackish and becomes often unfit for either drinking or irrigation

purposes during abnormally dry seasons. I venture to suggest that this difficulty will only be met with in comparatively shallow wells, which are constructed in the tertiary (eocene) beds and which, as we know, contain a great deal of salt in the form of strings and pockets and even in well-defined layers. I believe that borings sunk to below the cretaceous marls will meet with sweet water in sufficient abundance to neutralize the presence of the more brackish springs near the surface. None of the older bore-holes have gone to any great depths, and I believe that the deepest bore-hole (near Broach) made by Lieut. Fulljames in 1836 to 1839 did not reach 400 ft., so that it would be premature to pronounce against the possibility of obtaining an artesian supply of sweet water within Gujárát proper."

Flowing pipe in the bed of the Mahi River.

A very interesting occurrence is recorded in a report by Mr. F. D. Campbell, Executive Engineer on Special Duty, dated 9th February 1885. It is described as "that of the pipe now discharging in the bed of the Mahi river which was lately sunk at the time when some work connected with the foundation of the railway bridge piers was in progress. The end of that pipe entered at some depth a highly porous stratum, and the supply of water in it is so constant, that a jet or fountain, 6 feet high above the low water-level, is obtained, and, according to Mr. Crosthwaite's report, this water will rise in a pipe to 15 feet above that level; but this would still be 90 feet below that of the surface of the country, and would probably correspond with that in the wells not far from the river banks." The action in this case is properly speaking artesian, although not regarded as such by Mr. Campbell. Whenever the surface of the land is deeply cut into by the channel of a river, the level of saturation of the ground sinks rapidly in the neighbourhood of the river banks on account of the flow of undergound water towards the channel. Owing to the irregular disposition of permeable and impermeable layers common to all alluvial formations, one of the water-bearing strata underneath the river-bed might be enclosed by impervious strata in such a manner as to derive its supply from an area situated at no great distance from the river, but where the surface of the ground-water stands at a somewhat greater altitude than in the immediate neighbourhood of the river. It is probable that a similar phenomenon might take place in many river-beds; but in such a position the supply is usually not of much use. Of a similar nature is the occurrence mentioned by Mr. Medlicott as having taken place in the year 1884: "in sinking a well in the Ganges for one of the piers of the railway bridge at Benares, when the well was burst by a sudden influx of water from below a bed of clay rising to a greater height than the river water outside the well."[1]

(5) *Borings in other tertiary rocks.*

Boring for oil at Sukkur.

It is only in Gujárát that the tertiary rocks of India have been specially examined in search of water, but it may be mentioned here that one of the deepest borings in this country was sunk in tertiary strata in search of oil at Sukkur. Some of the most successful artesian wells in America, for instance those in Ohio, were originally experimental borings for oil. The Sukkur boring, however, yielded neither oil nor water (excepting a small flow at a depth of 865 feet), but it must be noticed that all the strata encountered were clays and compact limestones of a very impermeable nature. The boring reached a depth of 1,042·6. A complete record has been published by Mr. T. D. La Touche.[2]

As already mentioned in the separate descriptions, it is possible that the Karani, Coconada and Akyab borings although commenced in the alluvium entered tertiary rocks at a certain depth from the surface.

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[1] "Further considerations upon Artesian sources in the plains of Upper India. Rec. Geol. Surv. Ind., Vol. XVIII, p. 118.

[2] "Report on the Experimental Boring for Petroleum at Sukkur, from October 1893 to March 1895." Rec. Geol. Surv. Ind., Vol. XXVIII, pp. 55-59.

(6) *The Gondwanas.*

Structure and composition.

The Gondwana rocks, consisting as they do of alternating strata of sandstone and shale, appear well suited to the formation of artesian reservoirs. The topography is not always sufficiently varied to allow the expectation of a sufficient head to cause an overflow, though this might occur in some of the hilly tracts occupied by the upper Gondwanas, for instance, the Satpura range, of which there exists a geological section published by Mr. Medlicott,[1] showing great masses of various rocks dipping at low angles over large areas, the form of structure best suited for the collection of water in water-tight underground reservoirs. Nevertheless, as mentioned by Mr. Medlicott in his Report on Artesian borings, no overflow has been observed from any of the deep experimental borings put down in the Satpura coal-field during coal explorations at some of the places where the conditions for artesian water appear most favourable, although water under pressure has issued in sufficient amount to necessitate piping down to a considerable depth. The fact that no great difficulties have been met with from the inrush of underground water during mining operations in the lower Gondwanas shows that the strata traversed do not yield water in abundance. It is true that none of these mines are very deep, and it is possible that at greater depths strata might occur forming reservoirs with a larger intake area and an abundant supply of water under pressure.

Experiments in the Satpura Coal-Basin.

Water-supply of Raniganj.

A scheme was proposed in 1882 for supplying the town of Raniganj with water from the coal measures. But the proposed well was not to have been artesian: water was to be collected from a permeable bed of inferior coal by means of galleries driven into it, giving a considerable percolating area.

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[1] "Notes on the Satpura Coal-Basin." Mem. Geol. Surv. Ind., Vol. X, pp. 133-188.

Mr. Reader, Mining Specialist of the Geological Survey of India, has brought to my notice an occurrence that took place during some trial borings for coal in the Rampur coal-field in the Central Provinces. A flow of water issued from one of these situated near the Eeb river, forming a jet that rose above the surface. The occurrence was related to Mr. Reader by Messrs. Kilburn & Co., who put down the boring, but it had taken place previous to the detailed examination of the district, and the exact structure of the surrounding rocks has not yet been ascertained.

Boring in the Rampur coal-field.

The following information contained in a letter from Mr. C. Matthews, Engineer of the Diamond Drill Agency, Radhnagur, dated 17th August 1900, has been kindly communicated by Messrs. Kilburn & Co.: "Water commenced flowing from bore-hole at Dhoramanda at about 80 feet from surface, and greatly increased at depth of 120 feet, after passing through coarse grey free sandstone, and the water kept flowing continuously at about 600 gallons per hour, or equal to a discharge of a 1½" bore piping. In a trial to note to what height the water would rise above the bore-hole, two lengths of boring rods were connected to pulley head, and water rose full 20 feet height and kept overflowing. When the height was increased to 30 feet the water did not overflow. But this may be due to the water escaping below the casing tubes and working through the porous loose soil, and consequently the water could not accumulate as fast as it escaped through the soil, to gain sufficient head to overflow above 20 feet.

"The diameter of hole is about 4" to a depth of 40 feet, and from that depth to 830 feet it is 2" practically. The top of bore-hole was lined to a depth of 26 feet from surface, and below this depth the stratum was firm to withstand the sides from erosion or falling in.

"The position of bore-hole is in a valley between two ranges of hills, the height of the hills would not appear more than 80 to 130 feet above that of the bore-hole.

"The bed of stream is about 20 feet below bore-hole surface, and is running about 200 feet from nearest point of bore, the width would be about 30 to 40 feet in part. About 380 to 400 feet from surface, I noticed a greater volume of water running over the bore equal to nearly 2,000 gallons or thereabout, and I do not think that the flow of water got diminished. The lining tubes have been withdrawn from hole."

The Records of the Geological Survey contain accounts of a great many of these sets of trial borings for coal. In one case, in a description of an exploration in the Chhattisgarh coal-fields, mention is made of a boring where a sheet of water was struck at a depth of 14 feet, and gave a permanent flow at the surface.[1] Judging from the description, however, the site is in the low ground on the banks of a river, and as the water was tapped at such a small depth, it was no doubt in close connection with the ground-water at no great distance, the case being analogous to that of the Mahi river in Gujárát, or of the Ganges bridge at Benares.

Experimental borings in the coal-fields.

Along the east coast of the Peninsula there are several areas of upper Gondwanas whose strata dip at low angles towards the sea-coast, and which appear therefore suited to the existence of artesian conditions. Several experiments have been made to test these localities, but with small success so far. Such is the boring at Place's Garden, Kilacheri, in the Chingleput district near Madras. The work was originally undertaken by the Reverend S. Dominic, Superior of the Monastery at Place's Garden, and, on account of the great interest attached to the experiment, Government aid was granted on various occasions to enable the work to be pursued. On being consulted by the Government of Madras in 1891, when the boring was nearly 300 feet deep, Mr. Foote stated that he had reason to believe that a

Boring at Place's Garden, near Madras.

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[1] "Boring exploration in the Chhattisgarh Coal-fields," by William King. Rec. Geol. Surv. Ind., Vol. XIX, p. 229.

water-bearing stratum would be pierced near the base of the series where it rests on gneiss. The pressure might not be sufficient perhaps to cause a flow of water, but it would be within easy reach of pumps.

Sections situated a few miles north and north-west of the artesian boring show that the basement beds of the Gondwanas consist of a considerable thickness of permeable felspathic grit. The boring runs through a great thickness of black and dark grey carbonaceous clays which probably overlie that sandstone.

The Gondwana rocks exposed to the eastward and northward have been described by Mr. Foote.[1] They belong to the upper Gondwana stage. The rocks exposed belong mainly to the upper part of the series and consist of light-coloured shales, clays and sandstones. But in the boring they are found to be underlaid by the above mentioned dark grey and black carbonaceous shales ; in fact, it was through the boring that the existence of these dark clays first came to be known.

At the date of Mr. Foote's visit the boring had been carried through a considerable thickness of these impervious clays. It had been stopped for want of funds, but Mr. Foote considered that the water-bearing stratum was not far off, and that the boring should be continued until water is struck, or until the underlying gneiss is reached. Moreover, Mr. Foote pointed out that some of the dark carbonaceous clays are bituminous, and that, even if the boring were unsuccessful from the point of view of water, yet it might reveal the existence of coal seams or of bituminous shales worth distilling, or of valuable fire-clay. It would be, besides, of great scientific interest.

Since Mr. Foote's visit the boring has been deepened over 100 feet: in October 1899 it had reached a depth of 430 feet. Yet, the felspathic grit has not been reached, although a small band of sandstone four inches thick has been met with at a depth of 344 feet, and a second one 2 feet 2½ inches thick, at a depth of 359 feet. In a letter dated 19th November 1892, addressed to the Government of Madras, Dr. King recommended that the boring be carried down to a depth of at least 450 feet.

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[1] "On the Geology of parts of the Madras and North Arcot districts lying north of the Palar River." Mem. Geol. Surv. Ind., Vol. X, Part I.

Boring at Ellore.

Rocks of upper Gondwana age are found also near the mouths of the Godavari, and they have yielded water at Ellore in a boring which is still in progress at the present time. The strata dip towards the sea-coast to the south-east, in which direction they sink beneath volcanic rocks, of the age of the "Deccan Trap," Rajahmundry beds of the age of the Cuddalore sandstones, and finally alluvium. The upper Gondwanas here consist principally of sandstones, an upper series, the Tripety sandstones, and a lower one, the Golapilly beds. A series consisting principally of clays, the Kagavapuram shales, intervenes between the two sandstone groups. It has no great thickness but from its impermeable nature it provides a confining stratum to the water contained in the Golapilly sandstone, the other requisites for artesian action being provided by the lie of the stratification.[1] It is difficult to decide, without having seen any specimens, how much of the alternating sands and clays met with up to a considerable depth in the Ellore boring may belong to the alluvium, to the Rajahmundry beds or to the Tripety sandstones. Some specimens from a depth of 367 feet were forwarded to the Geological Survey Office and examined by Mr. Holland who identified them as probably belonging to the Ragavapuram shales. The circumstances therefore seemed favourable, on account of the probable proximity of the underlying Golapilly sands. In a letter, dated 13th June 1900, Mr. Holland had just expressed his opinion as to the advisability of continuing the boring, when a communication forwarded on the same date by the Engineer-in-Chief of the East Coast Railway announced that the boring had struck sand at a depth of 390 feet, and that water had risen in the tube to within 16 feet of the ground-level. The same communication contains a section of the boring up to a depth of 384 feet, from which the following record is reproduced :—

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[1] The geology of this country has been described by Dr. King in his paper on "the upper Gondwanas and other formations of the coastal region of the Godavari district." Mem. Geol. Surv. Ind., Vol. XVI, p. 195.

Section of Artesian Well-boring at Ellore.

Number of stratum.	Thickness of stratum.	Total depth from ground-level.	DESCRIPTION OF STRATA.
	Feet.	Feet.	
1	10	10	Black cotton soil.
2	10	20	Black clay hard and stiff. (Water level at 15 ft.)
3	10	30	Red clay.
4	20	50	Brown clay.
5	10	60	Brown clay and sand.
6	10	70	Nodular limestone and clay.
7	10	80	Yellow clay.
8	10	90	Brown clay interspersed with gravel.
9	40	130	Grey clay and lime nodules.
10	20	150	Red and yellow clay.
11	10	160	Grey and yellow clay.
12	10	170	Grey clay.
13	10	180	Yellow clay with kankar.
14	10	190	Decomposed yellow sandstone and clay.
15	10	200	Red and yellow clay.
16	10	210	Brown and yellow clay with kankar.
17	10	220	Yellow and grey clay with kankar.
18	10	230	Yellow and red clay with kankar.
19	10	240	Yellow and red clay and decomposed rock.

Section of Artesian Well-boring at Ellore—contd.

Number of stratum.	Thickness of stratum.	Total depth from ground-level.	DESCRIPTION OF STRATA.
	Feet.	Feet.	
20	10	250	White and red clay with nodules of laterite.
21	10	260	Yellow and grey hard stiff soil.
22	10	270	White sandy clay interspersed with large shingles.
23	10	280	White and brown clay interspersed with minute pebbles.
24	10	290	Yellow clay.
25	10	300	Light grey sandy clay.
26	10	310	Yellow streaky clay.
27	9	319	Yellow clay, light yellow sandy clay.
28	1	320	More or less pure sand, large grained.
29	10	330	Very hard stiff clay, yellow and white streaky clay.
30	10	340	Decomposed rock and clay. Decomposed streaky sandstone clay. White clay streaked yellow. Yellow, white and red streaky clay.
31	10	350	Yellow and white clay. Yellow and white chalky clay. White clay. Purple and brown clay. } Resembling chalk.
32	10	360	Purple and yellow clay. Purple and white clay.
33	7	367	Crimson clay (decomposed laterite) ; yellow and purple clay.
34	3	370	Pink clay with some yellow and white purple clay. } Resembling chalk.
35	7	377	Magenta and purple clay. Stiff clay and purple clay.
36	3	380	Yellow clay mixed with grey.
37	4	384	Light pink clay mixed with sand.

(7) *The Vindhyans.*

The Vindhyans, like the Gondwanas, consist largely of alternating layers of sandstone and shales, in addition to which, however, there are great masses of limestone. The strata are older than those that make up the Gondwanas, and the sandstones are very much more indurated. This must affect their permeability to a considerable degree, but whether so much as to prevent any decided flow, has never been tested.

Structure apparently favourable.

If the diminution of porosity caused by the induration of the sandstone does not oppose too great an obstacle to the flow of water, the structure is in many places an ideal one for artesian conditions. For instance, the great spread of Vindhyans in Central India might be compared to a series of shallow saucers of varying composition and of gradually decreasing size placed one upon the other. If the materials composing any of those layers are fairly permeable, there must be many places in the Saugor district, and in Rewah, Bhopal, Gwalior, and other States and Provinces of Central India where the sinking of artesian wells has every chance of success. One experiment made at a suitably chosen place might at once decide the question for a very large area. The testimony of the only boring that penetrated into this formation, the one at Agra, is inconclusive : whether the flow of mineral water that issued from the boring proceeded from the Vindhyans or not, the locality is at the edge of the formation, and the boring did not traverse any of those great alternations of shales and sandstones such as would be met with at suitable localities, and which, by their differences in permeability, might be expected to provide the water-tight layers necessary for confining an artesian reservoir.

A basin of very similar strata occupies considerable portions of Chhattisgarh. No experiments have been attempted there, but Mr. Medlicott, without giving any very decisive opinion, thought that the circumstances were fairly favourable.

The Kadapahs and Karnuls of the Deccan are not unlike the Vindhyans, but they are generally more disturbed.

(8) *The Deccan Trap.*

Need of more accurate information.

A system of rocks whose capabilities as water-bearing strata call for further research is the volcanic series known as the "Deccan Trap." The immense area occupied by that formation has almost entirely escaped geological investigation. The series consists largely of basalt, a rock of highly impermeable texture, but it is not known to what extent the existence of fissures and caverns may not affect its capacity in that respect. In some parts of the Bombay Presidency wells have been known to derive an abundant supply of water from fissures in the basalt.

Composition.

Moreover, the formation does not consist entirely of basalt : in some parts the sheets of basaltic lava are interbedded with great masses of tuff of more or less open texture. During intervals between the volcanic eruptions fresh water lakes were formed, in which sediments, the so called "intertrappeans," were deposited. Some of them are very compact limestones, but others are sands of loose texture. All these fragmentary rocks, tuffs, and intertrappeans might occur so placed as to form artesian reservoirs. But in our ignorance of the geological details of the formation, the existence of such reservoirs can only be indicated as a bare possibility without any reference to particular localities.

Structure.

In the western portion of their outcrop, near Bombay or in Gujárát and Kathiawar, these rocks have undergone a certain amount of disturbance. But in all other parts of the area occupied by the Deccan trap, the rocks are quite undisturbed and almost horizontal. Perfect horizontality of stratification would be incompatible with the existence of an artesian reservoir, unless accompanied (as it is sometimes) by irregularities of water-bearing capacity at various places. But it stands to reason that the horizontality of the strata that compose the "trap" formation is only apparent. Basalt is not formed on the sea-floor by some mysterious process of crystallisation as was thought by the adepts of the school of the "Neptunists" during the early part of the century, but it issues in a semi-fluid condition out of volcanic vents. Lavas relatively poor in silica and rich in iron, "basic" lavas in fact, like those that constitute such a large proportion of the Deccan trap formation, flow much more easily than do the more siliceous or "acid" ones. Yet their flow is not comparable with that of water, and when they solidify they are still in an inclined position, however slightly so. The huge area covered by the products of the eruptions whose accumulated masses probably rose into high mountains, has now been levelled to the shape of a plateau, and the low angles of dip of the overlapping sheets of lava get lost in the irregularities produced by denudation. The formation is practically horizontal when considered as one mass, and has only been studied as such. But there is no doubt that a more thorough examination will reveal great complexity of detail notwithstanding the uniformity of the general features, and it is by no means unlikely that it may bring to light the existence of artesian reservoirs of a very perfect character, if of limited extent.

Experiment at Mhow in Central India.

An experiment which seemed very promising was undertaken in 1884 at Mhow in Central India. In June 1884, a well was sunk at the engine shed of the Bombay, Baroda and Central India Railway. The junction of the "moorrum," or decomposed basalt, and of the hard rock is 35 feet below the ground surface. "Moorrum" is the name given to a peculiar form of surface decomposition of the basalt: it is permeable, and from it the surface wells of a large portion of the Deccan and of Malwa derive their supply. In the present instance, a certain amount of water issued at the junction of the "moorrum" with the underlying hard rock. The well was deepened to 90 feet below the surface of the ground without coming across any springs. A 2½ inch bore was put down at the bottom up to 13 feet, which in

96 hours filled the well up to 41 feet 6 inches from the surface of the ground. The diameter of the well was 25 feet, and the spring had delivered 49,459 gallons.

The locality does not seem to be in a very favourable situation, for it is only a short way north of the scarped face of the Vindhyan range.[1] Thus the surface of the ground at the locality where the well was sunk is at a higher level than the neighbouring region at a short distance further south, and it could not be expected under such conditions that the well would overflow. The following views were expressed by Mr. Medlicott on the subject of this experiment: "It would seem impossible for a sufficient head of water to accumulate for a surface delivery at Mhow. On the other hand, trappean rocks are very retentive of water and thus favourable for constancy of supply. The streams in such a country carry water much later than in similar ground formed of other rocks. This consideration would be in favour of a supply by deep wells, of which the engine shed well gives a very promising example." It is to be regretted that this experiment has remained an isolated one so far as is known.

Irregularity of the floor underlying the formation.

Besides the possible existence of reservoirs formed by loose textured tuffs and intertrappean sandstones, or by fissures and caverns in the basalt itself, it must be kept in mind that the products of the eruptions have overwhelmed a very irregular ancient land surface. In many places the decomposed rock surfaces composing this old land area and the ancient soil must form a more or less porous layer at the base of the volcanic formation, and, if the shape of this underlying surface could be known, it would be possible to select some likely places for experimental borings, as the porous layer might be locally disposed in such a manner as to form underground reservoirs. In the Deccan the thickness of accumulated lavas and tuffs is so great that the underlying rocks are concealed over considerable areas, and no accurate knowledge of the underlying surface could be arrived at except by a large series of experimental borings involving an expenditure out of all proportion with any results that could be reasonably predicted. But in Central India, where the thickness is not so great, the underlying rock shows itself in many places, and if these inliers of the older formations were mapped and their structure examined, it would be possible to arrive at a very fair idea of the shape of the surface upon which the strata of volcanic rocks are resting. I was able to ascertain this circumstance during a rapid inspection, which I made in 1898, of a part of Bhopal occupied by that formation: small mounds of Vindhyan sandstone stand out here and there above the almost level expanse of basalt. These are the tops of hill ranges buried beneath the solidified flows of volcanic lava. Before the lavas were poured over them, the Vindhyans were acted upon by the agencies of denudation just in the same manner as at the present day, and the topographical features thus produced bear a very distinct relation to their stratigraphy: once the lie of the different bands of strata composing them is revealed by the study of those inliers, it becomes easy to make out the shape of the surface with sufficient approximation, and thus decide on a choice of the places where water occurring at the junction of that old land surface and the overlying rock would be most likely to rise at or near the surface through a boring.

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[1] The name "Vindhyan" has been applied by the Geological Survey to a peculiar group of strata which have already been spoken of; but in a geographical sense the name applies to the rectilinear scarp north of the valleys of the Nerbudda and Son, the eastern part of which consists of "Vindhyan sandstones," but which, further west, is composed only of volcanic rocks.

(9) *Other rocks.*

The alluvium, the tertiary, the Gondwanas, the Vindhyans and allied formations, and the Deccan trap are the principal formations within which there can be any likelihood of artesian water being found, although even in these rocks the chances are very uncertain. In addition to these formations, there are enormous areas occupied by slates and metamorphic rocks, and by schists and gneisses, some of which have a more or less granitic tendency. Their highly crystalline and compact texture is incompatible with the existence of any great store of water. The very rare cases in which a flow of water has been obtained from such rocks are due to exceptionally disposed fissures. Not only can the possibility of such an occurrence be only very rare, but such cases could never be predicted from observations made at the surface. All the areas occupied by these rocks should be left out of consideration in the problem of artesian water-supply. In 1884 a boring was sunk in rocks of this class at Vizianagram, notwithstanding the adverse circumstances of the case, and after being carried to a depth of 350 feet, it failed to procure any supply of water.[1]

Boring at Vizianagram.

(10) *Conclusion.*

In conclusion, it may be stated that the possibilities of artesian supply in India are not fully understood and have been very imperfectly tested. But even if they were much greater than outward appearances would lead us to infer, still it would be a great mistake to think that they could be of the slightest utility in any extensive scheme of irrigation. On the other hand, leaving out of question the problem of irrigation on a large scale, there are many minor uses to which artesian water can be put to with great advantage, and viewed in that light, the subject is certainly deserving of attention and probably capable of development.

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[1] This boring is mentioned in the "Geological sketch of the Vizagapatam District, Madras," by William King. Rec. Geol. Surv. Ind., Vol. XIX, p. 143.

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VOL. XXXII, PART 2.

REPORT ON THE RAMPUR COAL-FIELD, *by* G. F. READER, *Mining Specialist, Geological Survey of India.*

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THE GEOLOGICAL SURVEY OF INDIA.

REPORT ON THE RAMPUR COAL-FIELD, *by* G. F. READER, *Mining Specialist, Geological Survey of India.* (With Map and 3 plates.)

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CHAPTER I.

INTRODUCTION.

When drawing up the Progress Report in camp on this field, time did not permit of my discussing all the data known and I confined myself directly to the main object of this survey, namely, "Is there any likelihood of finding a workable coal-seam?" Having now had a full opportunity of perusing all the papers relating to the various, apparently independent, explorations in this area, I am enabled to discuss in greater detail all the facts known which tend to answer that question, to show what still remains to be done and how in my opinion a conclusion can most speedily and effectively be arrived at.

Position and general Physical Features.

The part of the coal-field here described lies in the Central Provinces, about 22 miles N. N. W. of Sambalpur, in the bay formed by the junction of the Lillari nala with the Eeb river; its area is roughly 50 square miles.

The general level of the area is about 750 feet above sea-level. Apart from the Bilpahari range of hills to the north which rise some 400 to 500 feet higher and form a boundary to the Barakar rocks, and the hill, called Barakar on sketch-plan, to the south of Kiraruma, which rises about 100 feet above this average level, and perhaps the Luchkura range and Jamwapali hill, there is no very great departure from this level. Nevertheless the country is by no means of even gradient, for rugged little hills covered with laterite and thick jungle occur at every turn, and make the work of surface exploration a difficult one.

The symmetry of the sketch-plan attached is remarkable. The Eeb river and Lillari nala form a semi-circular curve having a centre situated somewhere in the Bilpahari range from which their tributaries evenly distributed appear to radiate. The rugged little hills above-mentioned, which form the watersheds for these tributaries, also possess a somewhat palmate arrangement striking off from the Bilpahari hills and forming, as it were, the framework of the area. This symmetry is enhanced by the Bengal-Nagpur Railway line which forms a more or less inner concentric curve.

Previous writers.

The area has already been treated on by Dr. Ball, in the Records of the Geological Survey of India, Vol. viii, Part 4, Dr. King, in the Records of the Geological Survey of India, Vols. xvii-3, xviii-4, xix-4, and xx-4, and by Mr. F. H. Smith, Deputy Superintendent of the Geological Survey of India. The former discussed it from a stratigraphical standpoint simply; the latter with a view to discovering its resources as a workable coal area. Dr. King's coal explorations were, however, very general—extending over the whole of the Chhattisgarh coal-fields. The present exploration is confined to a much smaller area and partakes more of the nature of a detailed Geological Survey.

Previous history.

The proposed construction of the Bengal-Nagpur Railway line through this known Barakar area and the great distance to the nearest coal supply, Warora—

the average lead from which source is 232 miles—brought the question of the coal resources of this field into prominence.

One thick band of upwards of 40 feet of carbonaceous and grey shales associated with some thin layers of coal near Durlipali, and several thin coal-seams near Bonjari and Khaliabahal, had long been known to exist in the Lillari nala. Dr. King was deputed to examine and report upon the prospects of this field as a staple source of coal supply. Under his directions ten boreholes and one shaft were put down which gave such poor results that no further action was taken in prospecting for coal until the discovery of a seam of coal under the site of the Eeb bridge (see Plan) on the Bengal-Nagpur Railway. On this discovery a grant was made by Government to the Bengal-Nagpur Railway Company to explore the coal area around Telanpali. In this exploration five boreholes and one shaft were put down. The general result was not encouraging, but on the report being submitted to Mr. Griesbach, Director of the Geological Survey of India, he, not being satisfied that the lower measures of Barakars which usually contain the best coal-seams had been sufficiently proved, advised the deepening of borehole No. 4 (near Kodopali — see Map) until the undoubted Talchir rocks were struck. In pursuance of this opinion Government sanctioned the work of carrying the boring to a depth of 600 feet. According to the boring record a seam of coal 7′9″ thick, with a 6″ band of stony shale in the middle, was struck at a depth of 347 feet, then for a hundred feet a remarkable succession of alternating bands of thin coal and shale were encountered, and the remaining 38 feet passed through fine sandstone, the hole being stopped at a depth of 485 feet in this stone before reaching the Talchirs. This boring result was deemed by Mr. Griesbach sufficiently encouraging to advise going on with the work for another 100 feet or so until the undoubted Talchir rocks were struck, unless the crystalline rocks were struck at a lesser depth. The boring contractors, however, said that the cost of drilling to this depth would be very great and Mr. F. H. Smith of the Geological Survey of India was deputed to visit th cspot to ascertain whether it could be regarded as reasonably certain that two borings to a depth of 500 feet would give the same information as one to a depth of 1,000 feet, and if strong evidence existed in favour of this conclusion, to mark the exact position at which the second borehole should be drilled with reference to the one under discussion. The examination did not answer this question and it was considered a better plan to select a site near Dhoramuda practically at the top of the Barakars and bore through the whole thickness of the Barakars on to the undoubted Talchirs or metamorphics, as the case might be, it being then estimated that the total depth would probably be below 800 feet. A borehole was put down here to a depth of 828 feet and passed through several shaly coal-seams finally stopping in the zone of Barakar rocks exposed, I think in the Lillari nala near Piplimal and several hundred feet above the top, geologically speaking, of the Kodopali (No. 4) borehole. It will therefore be seen that the lower measures of the Barakars have not been proved as was intended.

Dhoramuda borehole.

Before setting out for this area I was supplied with the one inch to a mile topographical map. It was my intention to put this map on a larger scale to make a working plan. Fortunately time did not permit of my doing this in Calcutta, for in the course of preliminary work in the field I was forced to the conclusion that the map was absolutely unreliable and not sufficiently accurate for recording geological observations.

Topographical Map.

The sketch-plan accompanying this report is one I made myself. It is the result of a loose needle survey made with a 2½ inch prismatic compass held in the hand. The chaining was done by my chaprassis who had never seen a chain before; any inaccuracies it may be found to contain, and I am alive to some, will therefore be readily understood. I did not intend at first to resurvey the whole area, but only the most crucial portions of it and join these on to the Atlas sheet. But when I found the latter so incorrect I was forced to complete the work for the purposes of this report. Only ten weeks were spent in this

Sketch-plan.

area, and before devoting myself to the direct object of this survey I had to turn my attention to these necessary though unforeseen preliminaries.

It will therefore be readily understood that my arrangements for accomplishing the intended object were impeded to avery great extent not more by loss of time than by fresh considerations introduced by the new map.[1]

CHAPTER II.

GEOLOGY.

The distribution of the rock formations is shown on the sketch-plan.

Crystalline rocks.

The crystalline rocks,—chiefly massive gneiss striking generally west-north-west and east-south-east—are coloured pink on the plan and form the bottom of a geological basin upon the uneven surfaces of which the Talchir and over-lying rocks were deposited.

Talchir rocks.

The junction of the gneiss and Talchir rocks is plainly seen to the south-east of Kiraruma, where it is traceable for some little distance to the south, and also in the neighbourhood of Putrapali.[2] The only other Talchir metamorphic boundary observed is the one shown to the north of Malda in the Bonum nala. But crystalline fragments are abundant to the west of Balput, and massive gneiss is exposed near the Lillari-Eeb confluence, therefore the boundary must be just north of these points.

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[1] As examples of the inaccuracy of the Topographical map I may mention—

On Topographical sheet.	*Actual distance.*
From Durlipali to Lillari-Eeb junction, 6 miles .	. 3·7 miles.
From Durlipali to Bonjari-Sumra Road, 2·7 miles .	. 3·6 miles.

The Eeb river, south of Rampur (of the Map), is shown to be running due south, whereas it runs west-south-west for two miles. The Bonum nala is most incorrectly delineated.

[2] This last place it was impossible to fix on the Topographical sheet, and as my own rough traverse does not include it, I cannot show its position.

The Talchir-Barakar (Karharbari ?) boundary is fairly well-defined in the Lillari nala where the fine-grained greenish grey sandstones of the Talchirs are seen within a few yards of the coarse-grained Barakar sandstones. At this point the Talchirs are striking north-east and dipping 5° to the north-west as also are the overlying Barakars. The next well-defined junction going east is at the Rampur Ghat, on the left bank of the Eeb river, where the Talchir rocks are seen within a short distance of the Barakars. Again a quarter of a mile east of Rampur the Talchir sandstones are observed at no very great distance from the Barakars. East-south-east of the Rampur Ghat about 1¼ miles Talchir shales can be seen dipping in a very irregular manner, the main trend of which is north. I saw no other decisive point to help in further defining this boundary to the south. On the west, although not actually seen, it is fairly certain that the boundary flanks the left bank of the Bonum nala from the north of Malda to ¼ mile east of Khit where it crosses the nala, sweeps round to the east of Jamwapali hill, swinging round to the west again on the north side of the hill and apparently striking the left bank of the Eeb river just south of Jamwapali village. From this point the boundary would appear to run practically north, striking the right bank of the Eeb river about ½ mile north of the Gorgor confluence.

There is a good exposure of Talchir sandstones on the left bank of the Eeb opposite Gondgura. Previously a straight boundary line from the east of Jamwapali hill up to this exposure and continued up to the exposure north of the Gorgor has been drawn, but a suspicious looking ridge running along the curve I have defined, seems to lend itself to a more natural delimitation.

It will be observed that Talchirs are also shown on the Plan faulted in to east of Gondgura. I shall treat on this exposure later in the paper.

So far then it will be seen that the Talchir rocks line the crystalline basin, and that in no instance do the Barakar rocks come in contact with the Metamorphics except perhaps to the west of Kiraruma where a peak of metamorphic rock is shown.

The thickness of the Talchirs has been estimated at 200 feet; from the few exposures where accurate dips and width of outcrops can be taken it is difficult to arrive at an estimate, but 200 feet is, I think, far too small a figure.

Barakar Group.

No actual contact of Talchirs and Barakars was seen, but in all the cases where Talchirs were exposed in the neighbourhood of Barakars, exposures of the latter where observed were always found to be dipping in the same direction and with practically the same amount of dip as the former.

The Barakars of this area have hitherto been treated in a very general manner, so that a brief record of any well-defined divisions and their distribution will be of use for the purposes of this paper. Four well characterised divisions are noticeable. Beginning at the top these are :—

1° A series of brown-weathering flaggy ferruginous sandstones probably upwards of 100 feet thick, which appear to form a transition series from Barakars to Kamthis.

2° A band of rather fine-grained sandstone of greyish color and about 40 feet thick.

3° The measures composing the greatest part of the thickness of the Barakars, consisting of thin and flaggy sandstones finely laminated micaceous sandstone, carbonaceous and micaceous sandstone, carbonaceous shales with thin coal bands interspersed and shaly coal-seams.

In this division it is remarkable that the argillaceous, arenaceous and carbonaceous shales predominate in the highest part; that they are present in the same proportion as the sandstones in the middle part, and that the sandstones are largely predominant in the lowest part. This feature very soon strikes one on noting the sections exposed in the Lillari nala. The record of the borehole put down during 1899 near Dhoramuda shews the gradation very well. By dividing the borehole into three equal lengths, the following table shows the gradation :—

	Top Length.	*Middle Length.*	*Bottom Length.*
	%	%	%
Argillaceous, arenaceous shales	60	54	22
Shaly sandstone	40	0	5
Sandstone	0	46	73
	100	100	100

All the boreholes which have been put down to test this Field were started in this division of the Barakars, except perhaps Nos. 1, 2a 3 and 4 of Dr. King and No. 1 of the Bengal-Nagpur Railway Company. The borehole 828½ feet deep put down near Dhoramuda during 1899 was started near the top of this zone, and I think the one put down during 1896 and 1897 near Kodopali (485') proves practically the bottom part.

To judge from all the data at present to hand, this zone would appear to be about 1,600 to 1,700 feet thick; it will be seen then that so far as these two boreholes (the Kodopali and Dhoramuda) are concerned there appears still to remain from 500 feet to 600 feet of this division to be proved. Horizontal section A will explain this better.

The sections of the two boreholes above referred to are appended and give in greater detail the succession of the rocks composing this division.

The above division of Barakars includes in its lower part the seam of carbonaceous shale and coal exposed near Durlipali and also "the tesselated ironstone bed" of Dr. Ball exposed a little higher in the section. Where exposed and weathered this ironstone bed is at once recognised. Dr. Ball identified it at Chuakani, about five miles north-north-east of Durlipali. The

Durlipali seam is about 500 feet from the bottom of this division.

4° In this, the lowest division of the Barakars, the gradation from shales to sandstones pointed out above appears to be completed; no arenaceous nor argillaceous shales were seen. At the top come conglomerates, resting unconformably on white sandstone—see section B—well exposed near the Eeb bridge both in the river-bed and also on the tops of the hills near Telanpali just north and south of the bridge. Below these come the typical coarse-grained Barakar sandstones towards the top of which a distinct white band of sandstone, about 8 feet thick in places, occurs. These sandstones are 100 feet or more in thickness and form the conspicuous line of hills running from Telanpali on the right bank of the Eeb to Malda on the left bank of the Bonum, ranging from 50 to 100 feet or more in height. The actual sandstones abutting on the Talchirs were nowhere seen but the lowest observed were coarse-grained though rather fine-bedded and micaceous.

Distribution of the various Zones of Barakars and general considerations.

The boundaries of the areas of the various zones into which I have divided the Barakar rocks are by no means easy to define all over the Field. It is possible, however, in some parts to establish approximate boundaries between these zones and by means of these considered in conjunction with data obtained from boreholes, to fix the relative horizons of the various seams proved and to arrive at a fair estimate of the thickness of the Barakars not proved by boreholes.

The sandstone conglomerate zone.

Considering first the lowest or sandstone series and starting in the Lillari on the west, no conglomerates are seen in the neighbourhood nor any of the massive coarse grits typical of this series. The hill between Kirarumą and Durlipali is of a type of sandstone (slightly massive) which can be referred to any of the series. Indeed, were it not that the rocks were conformably overlying the Talchirs, doubts would arise as to whether these rocks belong to the lowest zone.

Here then it will be seen to be a difficult matter to fix the boundary between the lowest or sandstone conglomerate zone and the next above or sandstone shale zone. For the purposes of this report, however, the boundary may be assumed to cut the Lillari just north of the Barakar hill midway between Durlipali and Kiraruma..

Going further to the east the next most suitable place for consideration of this boundary is between Kodopali and Bundia. Opinion here can be based upon the Kodopali boring on the one side and the assumed presence of Talchirs near Bundia in the Eeb on the other. As regards the borehole, it appears to have been started at about the same horizon as a shale bed supposed to be identifiable with the Durlipali seam. The borehole went down to 485½ feet and at 448 feet left the coal and shaly bed and entered into fine sandstone. This sandstone is probably the bed immediately overlying the conglomerates, and if such be the case marks the line of division between the two series. Allowing 120 feet as the thickness of the lowest series gives it a total of about 600 feet from the top of the borehole to the Talchirs. It is evident then that at about ⅙th of the distance from the Talchirs near Bundia to Kodopali boring the line of division must occur.

Following up the Eeb river from Rampur all the sections seen up to Gondgura belong without doubt to the lowest zone. Half a mile up the river from the Rampur Ghat, however, conglomerates are seen, so that, for our purposes, we may take the line as running just south of Telancachar.

The next point where anything like certainty obtains is near the railway bridge over the Lumchibahal nala where conglomerates are again seen. At Chuakani, a little village ¼ mile to the north of Begmar and ¾ west north-west of Job, the characteristic tesselated ironstone previously mentioned is seen. From this it follows that the boundary must run on the "crop" side (in this case eastward) of this exposure, the tesselated ironstone belonging to the zone above.

Taking it through Job itself the boundary must run round to the east of the hills north of Chuakani and hence out of our area.

On the plan accompanying this report I have washed the lowest zone dark neutral tint.

Evidence of Fault.

It will at once be noticed that the width of the area shown as occupied by this zone to the east is much greater than that to the south and that such extra width is apparently due to a fault marked as down throwing to the east. The data deemed sufficient to warrant the assumption of a fault as delineated on the map are :—

(*a*) Shales taken to be Talchirs were seen in the Modfia nala dipping west-south-west 15° and apparently cut off from the main bed by an intervening band of Barakars.

(*b*) The white sandstone band, in the lowest zone of Barakars, is seen occupying positions explainable by a fault. For instance, it is seen capping the Jamwapali hill dipping at an angle of 5° to the south-west; nearly a mile due south-west it is seen capping another hill and dipping in the same direction, and also at Telanpali where it has been quarried for bridge-building purposes.

(*c*) At the Eeb bridge a seam of coal has been found underlying a conglomerate band. At three other points marked R^5, R^6, R^7, on the map, coal also underlying a conglomerate bed is observed. It is presumed that these are four exposures of the same seam. Such being the case, it is evident that the outcrop is duplicated.

(*d*) The borehole No 1 of the Bengal-Nagpur Railway Company's grant put down, under Dr. King's directions, about 150 yards south-south-west of the Eeb bridge, failed to strike coal at a depth of 170 ft., although had the rocks kept their regular dip the Eeb bridge seam should have been struck at a much less depth.

It is upon the above evidence that I have felt myself justified in tracing the fault as shewn on the map, although in no instance is any actual break of rocks observable. About a mile north of Rampur on the left bank of the Eeb river the rocks are seen to be twisted about in a very strange manner, and again about one mile south-south-east of Rampur near a village called Tangadula, Talchir shales can be seen within a small area dipping in many directions and evidently indicating some disturbance.

If the estimate I have given of the thickness of the lower Barakar series be more or less correct, then from the map it will be seen that a very fair idea as to the amount of throw of the fault can be arrived at. Nevertheless it must be remembered that such thicknesses are only estimated, and moreover that the broad band marked as belonging to the first series of Barakars on the west (or upthrow) side of the fault is so deficient in good sections that only little weight can be given to this as a factor in arriving at the displacement of the rocks.

Sandstone shale zone.

This zone, which comes next above the one just described, extends up the Lillari to Dhoramuda, from whence its boundary sweeps eastward not far to the north of Belpahar station. The hills north of Job belong to this division, since the tesselated sandstone known to occur in its lower half is observed near Job, dipping westward, and somewhere between these hills and the Bilpahari Sitaram hills the divisional line must occur, but the obscurity of physical relations renders further discrimination almost impossible. It may, however, be added that, owing to the high dip and rising ground in the direction of the dip, the width of the zone in the neighbourhood of Job is less than in the Lillari nala.

The two upper zones being economically unimportant are not considered here.

Kamthis.

These rocks which overlie the Barakars consist at their base of brown weathering coarse-grained ferruginous sandstone. Since the conformity or otherwise of these beds with the Barakars is their only feature which is of use for the purposes of this report, their higher beds were not explored.

Conformity.

The relation of the Kamthis to the Barakars has frequently been considered. Dr. Ball favours the idea of unconformity but states that no actual section exhibiting unconformable superposition can be adduced. Dr. King (Rec. Geol. Surv. Ind., Vol. XVIII, pt 4, pp. 195 and 196) says in reference to this area: "I did not come across any section showing actual contact of the Kamthis on the Barakars, but there always appeared to be perfect conformity between the two." In Rec. Geol. Surv. Ind, Vol. XIX, p. 220, however, Dr. King concurs with Dr. Ball's view of unconformity.

So far as the area here described is concerned, the whole facies of the occurrence of the one formation on the other gives one the idea of perfect conformity and for the purpose of this paper I shall consider the relation as such.

CHAPTER III.

COAL EXPLORATIONS.

The boreholes put down during 1891 and 1892 by the Bengal-Nagpur Railway Company and all put down since are here considered. Boring explorations previous to that date have been treated on by Dr. King in the Rec. Geol. Surv. Ind. The sections of all the boreholes referred to will be found in the appendix.

After the discovery of coal on the site of the Eeb bridge, six boreholes and two small shafts were put down.

No. 1 Borehole was put down 230 yards south-west of the most westerly pier of the Eeb bridge.

No. 2 Borehole and a small shaft near the village of Luchkura.

No. 3 Borehole is described as situated 1½ miles from the west bank of the Eeb river and 2½ miles south of the railway. On reference to the map this will be seen to be incorrect. I am unable therefore to mark the site on the plan annexed.[1]

No. 4 Borehole and a small shaft are near Kodopali.

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[1] The sketches to hand purporting to shew the sites of the boreholes are of very little use, being tracings (and sometimes very rough ones) of the topographical map.

No. 5 Borehole near Job, north of the Railway.

No. 6 Borehole near Dhoramuda.

The coal, found at the Eeb bridge (hereinafter called the Eeb river seam) appears to occur only in the eastern half of the river-bed. Accurate levels were taken of the sandstone underlying the seam and indicated a dip of 1½° approximately to the east-north-east; the surrounding rocks however gave a dip of 5° to the south-west. As before stated No. 1 borehole was put down to the south-west of the bridge to prove the extension of the seam in that direction. It was expected that the Eeb river seam would be met with at a depth of 90 ft. at most, but although the borehole was carried to 170 feet, no trace of coal was found.

No. 1 borehole and the Eeb Bridge Seam.

In a report drawn up in 1892 on this exploration Mr. C. J. Dalby (Assistant Engineer of the Bengal-Nagpur Railway Company) has shewn in a very lucid section what appears to be the relation of the borehole to the Eeb river seam. I have reproduced this section—Horizontal Section B.—as it represents also my own idea on this point; but I must add that I differ from Mr. Dalby on the question of the general correlation of the seams shewn with those in the neighbourhood of Durlipali—there appears to have been a general consensus of opinion that the Eeb bridge seam was the same as the seam exposed, near Durlipali, in the Lillari, 6 miles west-south-west. The conglomerate shewn in the section is at the top of the lowest of the zones into which I have divided the Barakars.

In my own exploration in this area I was successful in unearthing a coal-seam outcropping at two points on the left bank of the Eeb about 1¾ and 3 miles down the river from the bridge, R^7 and R^8 on map.

That the seam unearthed at the first point R^7 is the same as the Eeb river seam the associated strata would appear to place beyond oubt, the overlying conglomerates being well in evidence. As regards the more southern exposure R^8 (near Rampur) identification is not so easy. No rocks are visible for some little distance on either side, and such as are seen are pitching about at high angles in all directions. Still a few conglomerates occur in the neighbourhood, and moreover the section of the seam, as deep as the pit sunk into it would be taken with the labour at hand, was to a favourable degree analogous with the more northern section, so that one is justified in assuming this to be also the Eeb bridge seam.

Reverting to Mr. Dalby's section—Hor. Section B—of the strata near the Eeb bridge, the coal-seam exposed at Lumchibahal bridge (R^5 on Map) is shown as analogous to the Eeb river seam. Now although before studying this section I had, judging from the associated rocks, arrived at the same opinion quite independently myself, it is perhaps only right to remark that the distance from the Eeb river seam to the Lumchibahal seam (R^5) is 1¾ miles and that good exposures are very few in number. It will be seen then that this correlation is open to doubt, but such unlooked for support is, I think, sufficient to allow of its being considered as above stated.

On such grounds then the Eeb river seam can be said to have been proved at four points. With the exception of the bridge itself, holes were put down this season at all of these points and the sections as deep as the pits could be carried with the labour at hand are :—

	R^6 near Rampur.	R^7 South of Bridge	R^5 Lumchibahal.	Eeb Bridge.
Conglomerate . . .	...	...	...	Beyond the statement that 16 feet of workable coal was met with, of which 8 feet were of excellent quality, no detailed section is to hand.
Grey shale	...	...	7' 0"	
Black earth	4' 0"	6' 0"	5' 6"	
Coal	4' 9"	2' 2"	1' 6"	
Bat	8"	1' 6"	│	
Coal	3' 1"	3' 3"	│	
Bat	1' 9"	│	│	
Coal anticipated . .	│	│	│	

When the first borehole failed to strike this Eeb river seam the idea of a fault downthrowing to the east appears to have been worked upon, and a borehole was started at Luchkura a little over 2 miles to the westward. Now the surrounding rocks are dipping at an average of 1 in 12 to westward, so that one would expect to find the outcropping rocks at the Eeb bridge about 900 feet deep at Luchkura, or assuming 900 feet of an upthrow to westward, surface rocks at the Eeb bridge to be at the surface at Luchkura. But although the idea of the throw of the fault is a very rough one we know that it can be but very little above 200 feet, if that much, and therefore a seam on the surface at the Eeb bridge should be expected to be about 700 feet deep at Luchkura. The borehole was 41 feet deep, and from the section it will be seen that four feet of coal was struck at a depth of 29 feet and that afterwards eight feet of shale was passed through. Strange as it may appear this coal-seam was at once said to be the same as the Eeb river and Durlipali seams. The difference in thickness was accounted for on the supposition that the seam had not been struck at the top but somewhere in the middle.

No. 2 borehole, Luchkura.

To further test the seam at this point a small shaft (53 feet deep) was put down a little to the west of the borehole and it was expected to have to go to a depth of at least 50 feet before touching the seam. At 36 feet, however, coal was struck and a 17 feet seam passed through, the shaft being stopped in sandstone. The Assistant Engineer (B.-N.Ry.), who was in charge of the shaft at the time, gave it as his opinion that the seam bored through in the borehole had not been struck in the shaft. I do not know the distance of the borehole from the shaft, but it seems to me that since four feet of coal was anticipated at 50 feet deep and the shaft was passing through coal at that depth and left it at 53 feet, some reason should have been given for the opinion. One point, however, is certain, that if the seam in the borehole and shaft are not the same, the lower one, borehole seam, must be direectly below the upper one, since the bottom of the 17 feet seam is 3 feet lower than the level at which the top of the borehole seam was estimated to occur. I was fortunate enough to see some of this seam which had

Luchkura *Shaft.*

been extracted lying by the side of the shaft. The heap had certainly been weathering for eight or nine years, but nevertheless it bore so great a resemblance to the Durlipali shale bed that I have assumed it to be the same; no data at present known except perhaps the difference of thicknesses of the seams—which, at such distant points as Durlipali and Luchkura, ought not to be allowed much weight—militate against this assumption, but opinions formed afterwards tended to confirm its correctness.

Reverting again to horizontal section B of strata near the Eeb river, borehole No. 2 (Luchkura) is seen so placed as to show that the seam it struck was the same as that exposed near Lumchibahal bridge, which I have correlated with my Eeb river seam. Considering now that the distance from Lumchibahal bridge to the shaft at Luchkura is a mile and a quarter and that the rocks exposed between these places are dipping at 5° to the westward, such correlation requires corroboration. Until such is forthcoming all that can safely be assumed must be based upon the dips of the rocks. Considering such then we can only say that at the Luchkura shaft a seam of coal seventeen feet thick has been proved, and that, from the dip of the strata, this seam appears to be overlying the coal-seam exposed at Lumchibahal bridge, from which it is apparently separated by a thickness of from 400 to 500 feet of measures.

If then the Lumchibahal bridge seam is, as I believe with Dr. King and Mr. Dalby, the same as the Eeb river seam and the Luchkura seam is identical with the Durlipali seam, it follows that the Eeb bridge seam appears to be some 400 to 500 feet or more below the Durlipali seam and this I am inclined to believe is the case. The next borehole, *i.e.*, No. 3, which might have given some evidence confirming this, cannot, however, be considered, its exact position not being known.

Borehole No. 3.

The Kodopali (No. 4) borehole does not afford any direct evidence on which correlation of seams can be made At a depth of 15 feet a 40 feet seam of coal was struck. To prove this seam of coal on a larger scale

Kodopali, No. 4 Borehole.

an experimental shaft was sunk on to it and several tons of coal extracted. I have not seen any report on the tests made with the coal extracted, but from the appearance of the coal stacked near the shaft, I would have judged the seam as worthless: subsequent experiments confirmed this. The original depth of the borehole was only 60 feet, it having been thought unlikely that there was more coal at a greater depth. As explained previously, Mr. Griesbach, Director of the Geological Survey, was not satisfied that there was no more coal at a greater depth, and Government acting on his advice sanctioned the deepening of the Kodopali borehole until the Talchir rocks were struck. This borehole was stopped at a depth of 485 feet, before reaching the Talchirs.

The coal proved by the borehole, at a depth of 15 feet, and in the shaft, was described as evidently the same as the Durlipali and Eeb river seams. The Kodopali Diamond Drill boring appears to have been put down on this assumption and is therefore supposed to have proved nearly 500 feet of measures below the Durlipali seam.

Kodopali No. 4, Diamond Drill boring.

Now beyond a similarity in the appearance of the seams and a very rough alignment of the Kodopali boring with the strike of the Durlipali seam, there are no grounds that I know of for correlating the Durlipali and Kodopali exposures, and when it is remembered that the distance from the Durlipali outcrop to the Kodopali boring is three miles, such an assumption can be, to say the least, only of little worth. There can be no doubt that the ground proved by the Diamond boring is near the base of what I have made my third zone, but at present there are no data sufficiently well substantiated to fix the exact horizon of the top of the hole. My own opinion is that it is some 200 feet or more above the top of the Durlipali seam. Be that as it may, the borehole verifies the Director's opinion that coal does exist below the seam proved in the shaft, and generally gives results sufficiently encouraging to justify further exploration of the lower Barakars.

Workable seams struck in the Kodopali boring.

On reading the record of the Kodopali boring, I selected six bands of coal worthy of consideration, namely:—

No. 1—at a depth of 42 feet and described in the boring record as—8 feet of shaly coal with 2 inch and 4 inch shale partings.

No. 2—at a depth of 340 feet 6 inches and described in the record as composed of—

	'	"	
Coal (shaly)	1	0	9' 6" of coal, and 1' 0" of shale.
Coal	2	0	
Carbonaceous shale	1	0	
Coal (shaly)	2	0	
Coal	2	6	
Coal (shaly)	1	0	

No. 3—at a depth of 352 feet 8 inches and composed of—

	'	"	
Coal	2	0	9' 7" of coal, 1'0" of shale
Carbonaceous shale	0	6	
Shaly band	0	6	
Coal	4	6	
Coal (stony)	0	6	
Coal	2	7	

No. 4—at a depth of 361½ feet and described in the record as composed of—

	'	"	
Strong coal	0	6	5' 4" of coal.
Coal	4	10	

No. 5—at a depth of 375 feet 9 inches and described as composed of—

	'	"	
Coal	2	6	9' 3" coal, 1' 0" shale.
Coal (stony)	0	6	
Coal	1	0	
Carbonaceous shale	0	3	
Coal	2	9	
Carbonaceous shale	0	9	
Coal	2	6	

No. 6—at a depth of 388 feet 7 inches and described as composed of—

	'	"	
Coal	2	6	8' 10" coal.
Coal (stony)	2	0	
Coal	0	3	
Coal (stony)	0	9	
Coal (fair 1 foot)	2	0	
Coal	1	4	

Had these sections been correct, each one of the above seams would have been thick enough to be worked at a profit supposing the coal to be of the average Indian quality. On comparing the record with the boring cores, however, I found that, with the exception of No. 3, each one of these seams had been badly recorded; carbonaceous and even argillaceous shales had been raised to the dignity of coal to such an extent that the idea of working these seams (except No. 3) could not be entertained. The section of No. 3 would be more correct if stated:—

		'	"	
	Carbonaceous shales	3	0	7' 1" of coal.
Coal		4	7	
	Stony shale	0	5	
Coal		2	0	
	Stony shale	0	7	
Coal		0	6	

Dhoramuda, No. 6 Borehole.

It has been remarked that the object of the Kodopali borehole was to prove the lower Barakar measures. At present as stated the lower Barakars have not been touched. It was evidently with this object still in view that the Director of the Geological Survey advised the deepening of the Kodopali borehole. Could this have been carried out at the time, a definite opinion as to the value of the field would in all probability by now have been arrived at. Unfortunately the boring contractors were not equipped with deep-boring tackle, and when later the work of proving the lower Barakars was undertaken, it was considered a better plan to bore through the whole thickness of the Barakar rocks. Owing undoubtedly in a very great measure to the inaccurate topographical map the thickness of the Barakars appears to have been under-estimated and as a consequence the site of the borehole—Dhoramuda—was chosen, too high, geologically speaking, for the object of the borehole to be accomplished with the tackle at hand.

It must not be understood, however, that this boring has served no useful purpose, for it certainly has proved that at this spot and consequently at all others on the same geological horizon, the depth at which good coal lies in the lower Barakar measures (supposing it to exist there at all) is such as to render it unworkable in the present state of Indian mining.

In a direct line from the Dhoramuda (No. 6) to the Kodopali (No. 4) borehole is a distance of fully six miles. The country is very jungly so that good surface exposures are practically absent. Under these conditions it is obvious that any figures intended, at present, to fix the relative horizons of the Kodopali and Dhoramuda borehole must be viewed with a very elastic mind. I have stated earlier in this paper that there appears to be still a thickness of some 500 to 600 feet of measures between the bottom of the Dhoramuda and the top of the Kodopali boreholes, but for the reason given above this can be but a very rough approximation.

Owing to their different geological horizons no correlation of seams in the (Dhoramuda) borehole can of course be established with those of the Kodopali borehole. Nos. 5 and 6 boreholes of Dr. King (Rec. Geol. Surv. Ind., Vol. XIX) appear to have passed through the same rocks as the Dhoramuda borehole.

Analogy of seams at Dhoramuda to those proved by Dr. King (Rec. Geol. Surv. Ind., Vol. XIX).

The seams met with at depths 18¼ feet and 62 feet in No. 6 borehole (Dr. King) may be taken as the representatives of the seams proved by the Dhoramuda borehole at depths of 772 feet and 685 feet 9 inches; and those at 203 feet, 114 feet, and 37 feet in Dr. King's No. 5 borehole as representatives of seams proved at Dhoramuda at 471 feet, 338 feet, and 309 feet.

The data for such supposition are as follows:—

Coal seams proved in the Dhoramuda (1890) Borehole.

Dr King's No. 5 borehole lies (as nearly as I can gather from the Records) ⅝ mile to the rise of the line of strike of the beds at the Dhoramuda borehole. The dip is not very constant over the intervening country, but 1 in 12 is perhaps a fair average. From this it can be found that a seam near the surface at the No. 5 borehole of Dr. King (near Khaliabahal) will be about 276 feet deep at Dhoramuda. This gives the correlation for Dr. King's No. 5 borehole, and since the main sandstone bands fall in more or less with this, little doubt can remain as to its probable correctness. Reasoning similarly with Dr. King's No. 6 borehole the carboniferous bands proved can be correlated as illustrated. This correlation is of great use in indicating which of the seams proved by the Dhoramuda borehole are exposed in the Lillari nala. For instance, Dr. King (Rec. Geol. Surv. Ind., Vol. XIX page 212), shews that the first coal struck in his No. 5 borehole was the same as that exposed near Khaliabahal and the first in his No. 6 borehole that exposed near Bonjari. From the boring record of the Dhoramuda hole one is able to mark out eight seams of coal as appearing to be of workable thickness :—

			Ft.	dec.
1°	described as	24 ft. of carbonaceous shale and coal at	255	„
2°	„ „	16 ft. of coal (shaly) at	309½	„
3°	„ „	10 ft. of coal (shaly) at	471	„
4°	„ „	3 ft. 6 ins. coal (shaly) at	504	„
5°	„ „	15 ft. 6 ins. coal shaly) at	644	„
6°	„ „	9 ft. 0 ins. coal (shaly) at	672	„
7°	„ „	5 ft. 9 ins. coal (shaly) at	685½	„
8°	„ „	4 ft. 0 ins. coal (shaly) at	768	„

No. 1 in Dhoramuda borehole, the Khaliabahal exposure.

On looking at the boring core it can at once be seen that Nos. 1, 3, 4, 5, 6 and 7 can be dismissed from further consideration as of no practical use whatever, being simply cases of bat, *i.e*, bituminous shales—sometimes grit sandstones included,—raised to the dignity of coal. It is of interest to note, however, that No. 1 is indentical with the Khaliabahal exposure. Now during my work in the field this season I sank a little shaft in this exposure and satisfied myself that it did not contain coal of sufficient thickness or quality good enough to be workable.

The section obtained was:—

	Ft.	In.
Top clay	2	0
Shale	0	4
Coal	0	4
Shale	0	4
Shale with coal pipes	2	4
Shale	1	0
Coal	0	6
Shale	0	5
Coal	0	2
Shale	0	2
Sandstone base		

There is as will be seen 1 foot of coal in the whole section. To form an idea of the nature of such coals, I extracted some of this foot of coal and tested it getting upwards of 35 per cent. of ash. Dr. King's general analysis of the whole seam gave :—

	%
Moisture	8·20
Volatile matter	22·21
Fixed carbon	25·16
Ash	44·43
	100·00

No. 7 in Dhoramuda borehole, the Bonjari exposure.

Perhaps also it will be as well to record that the No. 7 seam is the one exposed near Bonjari and therefore the same as Dr. King's 7 foot seam at 62 feet deep in his No. 6 borehole. I also sank a small shaft into this exposure and obtained the following section :—

	Ft.	In
Carbonaceous shale	2	0
Ironstone	0	3
Carbonaceous shale	2	3
Coal	0	
Carbonaceous shale	1	0
Coal	0	5
Carbonaceous shale	0	9
Coal	0	5
Carbonaceous shale	1	4
Coal	0	2
Carbonaceous shale	0	7
Sandstone base		

Here again then is an insignificant thickness of coal. A test on the coal alone gave upwards of 35 per cent. of ash. An average analysis throughout the seam is given by Dr. King :—

	%
Moisture	5·44
Volatile matter	25·03
Fixed carbon	29·22
Ash	39·31
	100·00

These two seams just discussed (Nos. 1 and 7) may be taken as typical of the other four (Nos. 3, 4, 5, and 6), and all can therefore be dismissed from further consideration.

This leaves us then with only two (Nos. 2 and 8) coal-seams of workable thickness in the Dhoramuda borehole. No. 2 described in the Record as 16 feet of shaly coal appears from the core to be—

	Ft.	In.	
Coal	3	7	7' 3½" coal, 1' 0½" shale.
Shaly band	0	8	
Coal	1	11½	
Shaly band	0	4½	
Coal	1	9	

No. 8 is as described 4 feet of coal.

CHAPTER IV.

WORKABLE THICKNESSES OF COAL PROVED.

So far then only four seams of coal out of the many struck have upon examination proved to be of workable thickness. Beginning at the top and in descending order these are:—

1° The seam proved in the Dhoramuda borehole at a depth of 309¾ feet, the section of which is given just above and is shewn to be composed of 7 feet 3½ inches coal with one foot of shale interbedded.

2° The seam proved in the Dhoramuda borehole at a depth of 768 feet, containing four feet of coal.

3° The seam proved in the Kodopali borehole at a depth of 352⅜ feet, composed of 7 feet 1 inch of coal with one foot of shale interbedded.

4° The Eeb bridge seam of which the best section obtained shows 7 feet 10 inches of coal with 8 inches of bat (hard bituminous shale) interbedded.

Quality of the coal.

I have made careful analyses of these four seams and tested their calorific powers.

It must be remembered, however, that the samples of Nos. 1, 2, and 3 seams, of which the analyses were made, were taken from the cores of the diamond drill boreholes put down in February 1899

(Dhoramuda) and 1896 (Kodopali). The cores had of course weathered, but I am inclined to think that the analysis may be taken as fairly representative of the seams, in the neighbourhood of the boreholes.

The tests on the Eeb bridge seam were made on fresh general samples extracted by myself from little shafts put down this year near the outcrops.

The following are the results of the analyses :—

NO. 1.—DHORAMUDA AT A DEPTH OF 309¾ FEET.

	Top 3′ 7″. %	Middle 1′ 11½″. %	Bottom 1′ 9″. %
Moisture	7·3	7·9	9·8
Volatile matter . . .	21·9	25·4	21·1
Ash (white) . . .	40·0	35·1	30·7
Fixed carbon . . .	30·8	31·6	38·4
	100·0	100·0	100·0

NO. 2.—DHORAMUDA AT A DEPTH OF 768 FEET.

Moisture	6·2
Volatile matter	19·0
Ash (yellowish white)	31·4
Fixed carbon	43·4
	100·0

NO. 3.—KODOPALI AT A DEPTH OF 352⅔ FEET.

	Top 4′ 7″. %	Bottom 2′ 6″. %
Moisture	4·6	7·5
Volatile matter	17·5	19·6
Ash (reddish)	35·3	34·4
Fixed carbon	42·6	38·5
	100·0	100·0

NO. 4.—THE EEB BRIDGE SEAM.

	R^7 (south of Bridge). %	R^6 (near Rampur). %
Moisture	8·0	9·0
Volatile matter	20·9	24·3
Ash (buff)	18·9	11·8
Fixed carbon	52·2	54·9
	100·0	100·0

No. 1.

Nos. 2 and 3.

Considering the above results it will be seen that Nos. 1, 2, and 3 are not of good enough quality to be of themselves workable and it is a question whether No. 1 can at present be profitably used for any purpose. As time goes on, however, it is not unlikely that a seam even of this quality may be in demand, but for the present I do not think such a seam can be considered as a factor in the value of the field. No. 2 is a little better, but is a thinner seam. It is not, however, unlikely that in the near future this seam together with No. 3, which is of about the same quality, but a little better section, may be worked for local consumption, mills, etc. For high temperature, *e.g.*, smelting, etc., the seam is of but small value.

No. 4[1] is the seam "par excellence" of this coal-field. The coal is of good steam quality and is eminently suited for locomotives or stationary boilers. It is free burning, does not clinker and leaves a buff coloured ash. Its average calorific power is 12·7. It is non-caking and compares very favorably with Raniganj coals.

Eeb River Seam.
Practical considerations.

The Eeb river seam then if it can be proved to cover sufficient workable area and maintain section and quality similar to that proved at the two exposures,

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[1] The analyses of the samples from the two outcrops of this seam, *i.e.*, R^7 and R^6, will be seen to differ considerably in amount of ash. In the earlier part of this paper I have reasoned that these outcrops are outcrops of the same seam. The possibility of their being two seams must not, however, be overlooked; in fact the difference in percentage of ash is an argument in favour of this, but perhaps not a very strong one, since the two exposures are a mile and a quarter apart.

R^7 and R^6, can be considered, *per se*, profitably workable. There is every reason to suppose that the seam extends over the greater portion of the Barakar area being low down in the Barakar horizon. On the sketch-plan I have marked what from present geological data would appear to be the outcrop of this seam, but as has been previously remarked, data are very few and surface evidence wanting, so that the mapping of the outcrop can only be looked on as an approximation.

The question arises as to how to prove the extension and capabilities of this seam. The best way, of course, is to prove the outcrop of the seam for some distance. Starting say from R^6 exposure near Rampur a series of hand boreholes might be put down along a line going westward towards Durlipali. Such boreholes, however, must be put down in a systematic manner and the exact relationship of the section of any one to that of the previous one and the Eeb river seam be ascertained before another borehole is put down further to the west. The same method might also be applied along the line of the outcrop marked as running northwards from Rampur, but sufficient ground would, in all probability, be proved in the first case to warrant mining operations and plant. As far as the outcrop on the right bank of the Eeb river is concerned, it should not be lost sight of even if, as supposed is the case, it represent a patch cut off by a fault from the main area. There is ample room for a small plan; it is not unlikely, however, that water will be a trouble.

General consideration.

I have stated previously that the bottom of the Dhoramuda borehole appears to be from 500 to 600 feet above the top of the Kodopali borehole and that the bottom of the Kodopali borehole has not struck the Talchirs.

Sketch section A illustrates what I think is approximately the relation of these boreholes to one another. I have scored in red the lengths unproved by the Dhoramuda and Kodopali boreholes which may amount to from 600 to 800 feet or more.

The thickness of measures above the Kodopali borehole—reference B in Horizontal Section A.—appears to have been proved by Dr. King (Vol. XX, Rec. Geol. Surv. Ind., boreholes Nos. 7 and 8), but since no record is kept of the exact positions of the boreholes put down in this exploration and no relationship definitely established between them, it is not possible to draw up a complete vertical section nor even to be certain that the ground is thoroughly proved. However by surface observations I satisfied myself that no workable coal-seams were present in this zone, and I am therefore able to dismiss it from further consideration.

As regards the lower unproved length—reference D, Section A—it is in this zone that the Eeb river seam occurs. I gave special attention to the area occupied by the rocks of this length, but was unable to get data from which to compile a complete section. In my preliminary report on this area I advised that a borehole should be put down to prove this lengthor he Kodopali borehole completed to the Talchir Rocks. A good place for such a borehole would be ⅜ mile east-south-east of Kodopali. A borehole so placed should pass through the Eeb seam and be of great help in fixing its exact horizon and facilitating the determination of its outcrop.

Conclusion.

From a commercial point of view then I would advise further enterprise, a good seam of steam coal and also two seams of coal of rather inferior quality, but of workable section (which might be used for mills and local consumption) having been proved to exist within easy reach of the railway. It is necessary, however, before putting down plant to work the main seam, to prove its extension. It has been recommended that, while this work is being undertaken, the lowest 200 feet of the Barakar measure should be proved by a Diamond boring put down on to the Talchirs about ⅜ mile east-south-east of Kodopali. It is not possible to state with any idea of certainty what the actual depth of such a borehole will be, but I do not think it will exceed 600 feet—it will probably be much less.

Appendix.

BORING RECORDS, RAMPUR COAL-FIELD.

The Dhoramuda Borehole, Lillari Valley.

Strata passed through.	*Thickness in feet.*	
Alluvial clay (sandy)	14	
Soft loose brown grey sandstone (coarse)	5	
Brown and white sandstone	6	
Carbonaceous shale	5	
Sandstone	2	
Grey sandy shale	2	
Dark shale	3	
Grey sandy shale	3	
Dark slaty shale	3	
Grey sandy shale	7	
Coal	1	
Shale (sandy)	6	
Sandstone	5	
Coal	0·25	
Shale, grey	7·5	
Coal	1·75	
Sandstone	3	
Sandy shale	4	
Carbonaceous shale	0·5	
Sandy shale	3	
Shale clay	4	
Sandy shale	6·5	
Grey sandstone	6·5	
Grey shale	1	
Grey sandy shale	6	
Shaly sandstone	7	
Coal (shaly)	1	
Shaly sandstone and grey shale	19·75	
Coal (shaly)	1·25	
Grey sandstone	18	
Coal (shaly)	1	
Grey sandstone shales	26	
Coal (shaly)	2	
Fossiliferous shales	14	
Carbonaceous shales carrying thin bands of shaly coal	10	
Sandy blue shale	5	
Shale carrying coal	1·25	
Grey shaly sandstone	41·75	
Carbonaceous shale and *coal* (shaly)	24	(1)
Blue and grey sandstone (shaly)	30·75	
Coal (shaly)	16	(2)
Argillaceous shales	12·25	
Carbonaceous shales with *3" to 6" bands of coal and shaly coal*	21·5	
Grey sandstone	54·5	
Grey and blue shaly shales	50·75	

	Thickness in feet.	
Black trap and carbonaceous shale	6·25	
Coal (shaly)	10	(3)
Grey and blue shales	23	
Coal (shaly)	3·5	(4)
Blue and grey sandy shales	8·5	
Coal (shaly)	1	
Blue and grey sandy shales	24	
Coal (shaly)	1	
Grey sandstone carrying *strings of coal*	28	
Coal (shaly)	1·5	
Grey sandstone	12·5	
Coal (good)	1·25	
Grey and blue shale and sandstone	58·75	
Coal (shaly)	15·5	(5)
Sandy grey shales with 3″ *seams of coal*	8·5	
Coal (shaly)	2	
Carbonaceous shales with *coal*	2	
Coal (shaly)	9	(6)
Grey shaly sandstone	4·75	
Coal (shaly)	5·75	(7)
Shale and sandstone	5·5	
Coal (shaly)	·5	
Dark blue shale and grey sandstone	70·5	
Coal (shaly) in parts fair	4	(8)
Carbonaceous shales and coal shales	15	
Grey and brown sandstone	21·5	
Dark blue carbonaceous shales	7	
Dark grey shale	8	
Carbonaceous shale with coal	2	
Blue shale	2	
TOTAL	828½ feet.	

THE KODOPALI BOREHOLE.

Alluvial soil	2·5	
Laterite	3	
Ironstone band	4	
Chalk	6	
Bituminous shales	18·5	
Shaly coal with 2″ and 4′ shale partings	8	(1)
Shale	3	
Argillaceous shale	10	
Fine dark grey shaly sandstone	15	
Argillaceous shale	1	
Fine dark grey shaly sandstone	10	
Blue argillaceous shale	7	
Coarse grey sandstone with fossiliferous dark partings	2	
Slaty shale	5	
Coal (shaly)	2	

	Thickness in feet.
Argillaceous shales	6
Fine bluish grey shaly sandstone	14·75
Hard grey sandstone	1·25
Coal (shaly)	2·5
Argillaceous shales, light and dark	19·5
Fine grey and blue sandstone	7
Shale	1
Grey sandstone (shaly)	4
Argillaceous blue shales	10
Shaly coal	1
Hard brown clay	0·5
Shales	1·5
Grey sandstone, micaceous and soft at top part	7
Grey sandstone coarse and fine with shale partings	27
Grey shaly micaceous fine blue sandstone	8
Coarse grey sandstone with shale partings (conglomerate)	1·25
Grey shale	0·5
Coal	0·25
Grey shaly blue sandstone	5
Blue shale	5
Grey shaly sandstone	14
Slaty dark shales	3·5
Argillaceous shaly sandstone	2·5
Blue shales, argillaceous	7
Grey sandstone shaly and micaceous	15
Conglomerate	1
Shale with pyrites	1·2
Shale	0·3
Grey sandstone (coarse)	1·5
Shale	1
Very coarse grey sandstone with pyrites	21·5
Shale	3·5
Clay shale with white specks	3
Carbonaceous shale	1·5
Shale (coaly)	1
Carboniferous shale	4
Do. (coaly)	0·5
Carboniferous shale	3
Do. (coaly)	0·5
Carboniferous shale	1
Do. (coaly)	0·5
Carboniferous shale	1
Do. with light shale partings	9
Coal (shaly)	1·6
Shale	1·4
Coal	·6
Shale, light and carbonaceous	8·4
Coal	1
Carbonaceous shale	1

	Thickness in feet.	
Coal, shaly	1	(2)
Coal	2	
Carbonaceous shale	1	
Coal, shaly	2	
Coal	2·5	
Coal, shaly	1	
Carbonaceous shale	1·5	
Coal	2	(3)
Shaly band	0·5	
Carbonaceous shale	0·5	
Seam of *Coal*	4·5	
Stony *coal*	0·5	
Coal	2·7	
Shale	1·3	
Coal	1	
Carbonaceous shale	0·7	
Coal	0·5	
Carbonaceous shale or strong *coal*	0·5	(4)
Coal	4·8	
Shale	3·0	
Stony *coal* or carbonaceous shale	1·0	
Coal	2·5	(5)
Stony coal or carbonaceous shale	0·5	
Coal	1·0	
Carbonaceous shale	0·25	
Coal	2·75	
Carbonaceous shale	0·75	
Coal	2·5	
Carbonaceous shale	1·5	
Coal	1·2	
Carbonaceous shale	0·5	
Coal	0·33	
Stony coal or carbonaceous shale	0·5	
Coal	2·5	(6)
Stony *coal*	2·0	
Coal	0·25	
Stony *coal*	0·75	
Coal (fair 1 foot)	2·00	
Coal	1·33	
Stony *coal* or carbonaceous shale	0·33	
Coal	0·50	
Stony *coal* or carbonaceous shale	0·50	
Coal	0·50	
Carbonaceous shale	0·72	
Coal	0·50	
Carbonaceous shale	1·33	
Coal	0·75	
Carbonaceous shale	0·33	
Coal	0·75	
Carbonaceous shale	0·75	

	Thickness in feet.
Coal	1
Carbonaceous shale	1·33
Coal	0·50
Carbonaceous shale	1·50
Coal	0·50
Carbonaceous shale	0·25
Coal	0·25
Carbonaceous shale	0·66
Coal	0·50
Carbonaceous shale	0·83
Coal	2·50
Carbonaceous shale	0·33
Coal	0·66
Carbonaceous shale	0·66
Coal	0·20
Carbonaceous shale	1·33
Coal	0·50
Carbonaceous shale	1
Coal	0·20
Carbonaceous shale	1·20
Coal and shaly beds continue for 37 ft.	37
Fine sandstone	37·5
TOTAL	485·5 feet.

No. 5 BOREHOLE.

Surface soil	4
Various clays	10
Dark brown shaly sandstone and clay	1
Carbonaceous shale	6
Fine grey shaly sandstone	1
Carbonaceous shale	2
Slight carbonaceous fine shaly sandstone	4
Grey shaly sandstone	1
Carbonaceous shaly sandstone	2
Grey and carbonaceous shaly sandstone	6
Coal	9
Carbonaceous shale	4
shaly sandstone	1
shale	1
shaly sandstone	1
shale	1
and grey shaly sandstone	4
White shaly sandstone	6
Carbonaceous shaly sandstone	5
" shale and grey shaly sandstone	13
Grey shaly sandstone	1
Carbonaceous shale	5
Coal	1

	Thickness in feet.
Carbonaceous shale	6
Coal	4
Carbonaceous shale	12
Coal and shaly sandstone	1
Carbonaceous shale	1
Hard grey shaly sandstone	1
Coal	15
Grey shaly sandstone	8
Carbonaceous fine shaly sandstone	3
,, shale	10
Grey shaly sandstone	20
Yellow and mottled clays	3
Carbonaceous shaly sandstone	4
White shaly sandstone	3
Grey shaly sandstone	2
White sandstone	15
Carbonaceous shaly sandstone	1
,, shale and coal	2
Coal	15
Carbonaceous shale and coal	1
Grey shaly sandstone	5
TOTAL	221 feet.

Water tapped at 14 ft. which flowed over surface to the end.

No. 6 BOREHOLE.

Surface soil	9
Soft brown sandstone	3
Soft yellow sandstone	3
Soft brown sandstone with clay	3
Brown sandy clay	3
Grey shaly sandstone	6
Brown ,, ,,	1
Carbonaceous shaly sandstone	4
Grey shaly sandstone	6
Carbonaceous shale	9
,, and *coal*	9
Coal	7
Carbonaceous grey shaly sandstones and *coal*	1
Grey and carbonaceous shaly sandstone	4
Carbonaceous shaly sandstone	3
Coal and carbonaceous shale	6
Carbonaceous fine shaly sandstone	5
Grey shaly sandstone	1
Grey and yellow sandstone	1
Grey shaly sandstone and *coal*	2
Grey shaly sandstone	2

	Thickness in feet.
Yellow shaly sandstone	3
Carbonaceous shale	6
„ „ and grey shaly sandstone	3
„ shaly sandstone	1
Grey shaly sandstone	50
Coal	1
Carbonaceous shale	4
Coal	4
Carbonaceous shale and *coal*	6
Coal	1
Carbonaceous shale and *coal*	4
Coal	6
Carbonaceous shale and *coal*	2
Coal	9
Carbonaceous shaly sandstone	2
„ shale	1
„ shaly sandstone	6
„ shale	2
„ shaly sandstone	4
„ shale	4
„ shaly sandstone	1
„ shale	1
„ shaly sandstone	2
Yellow sandstone	8
White sandstone	12
Carbonaceous shaly sandstone	3
„ shale	19
TOTAL	258 feet.

Water tapped at 26 ft.

NO 7 BOREHOLE.

Surface soil and variegated clays	15
Vari-coloured shaly sandstone	16
Carbonaceous shale	1
Coal and carbonaceous shale	1
Carbonaceous shale	1
Coal	3
Carbonaceous shale	21
Grey shaly sandstone	5
Carbonaceous shale	4
Grey shaly sandstone	1
Carbonaceous shale	8
„ shaly sandstone	8
„ and grey sandstone	10
„ shaly sandstone	2
„ shale	1
„ shaly sandstone	4
„ and grey shaly sandstone	15

	Thickness in feet.
Carbonaceous shale	4
,, fine shaly sandstone	1
,, shale	3
,, ,, and *coal*	4
Coal	4
Carbonaceous shale	9
TOTAL	141 feet.

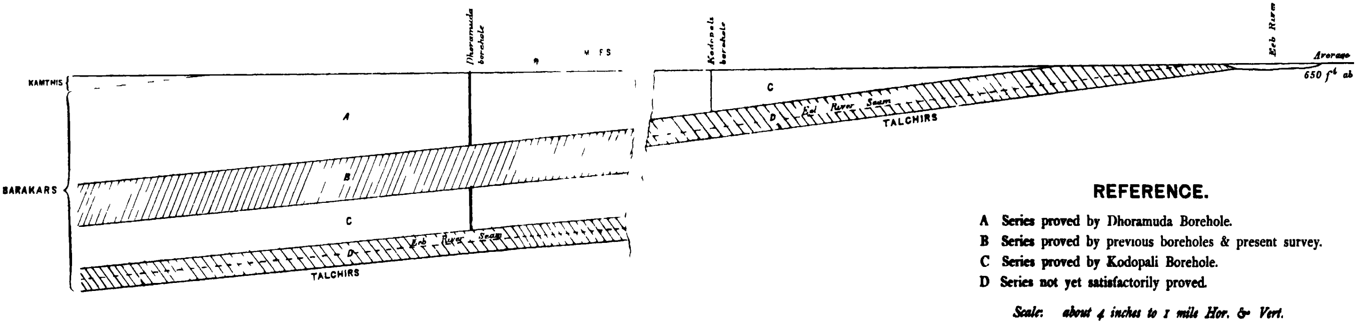
Water tapped at 15 ft.

No. 8 BOREHOLE.

Surface soil and clay	6
Vari-coloured sandstones and clays	19
Slightly carbonaceous brown shaly sandstone	2
Carbonaceous shale	4
,, ,, with a little *coal*	1
,, shale	8
,, grey shaly sandstone	15
,, shale	3
,, fine shaly sandstone	10
,, shale	3
,, ,, and *coal*	9
,, ,, and shaly sandstone	28
,, ,, and *coal*	3
,, ,,	10
Coal and carbonaceous shale	3
Carbonaceous shale	13
Coal	4
TOTAL	141 feet.

Water tapped at 20 ft.

G F Reader



REFERENCE.

- A Series proved by Dhoramuda Borehole.
- B Series proved by previous boreholes & present survey.
- C Series proved by Kodopali Borehole.
- D Series not yet satisfactorily proved.

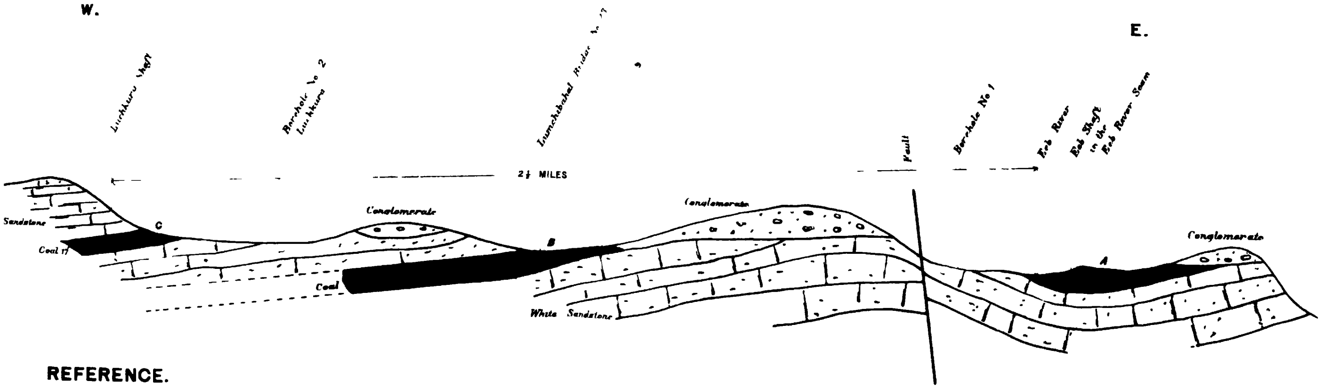
Scale: about 4 inches to 1 mile Hor. & Vert.

HORIZONTAL SKETCH—SECTION A

FROM NEIGHBOURHOOD OF RAMPUR ON THE EEB RIVER THROUGH KODOPALI & DHORAMUDA.

showing the Barakar Measures proved & unproved by the Kodopali & Dhoramuda boreholes.

G. F. Reader



REFERENCE.

A Eeb River Seam
B Supposed ditto
C Durlipali Seam ?

HORIZONTAL SKETCH—SECTION B

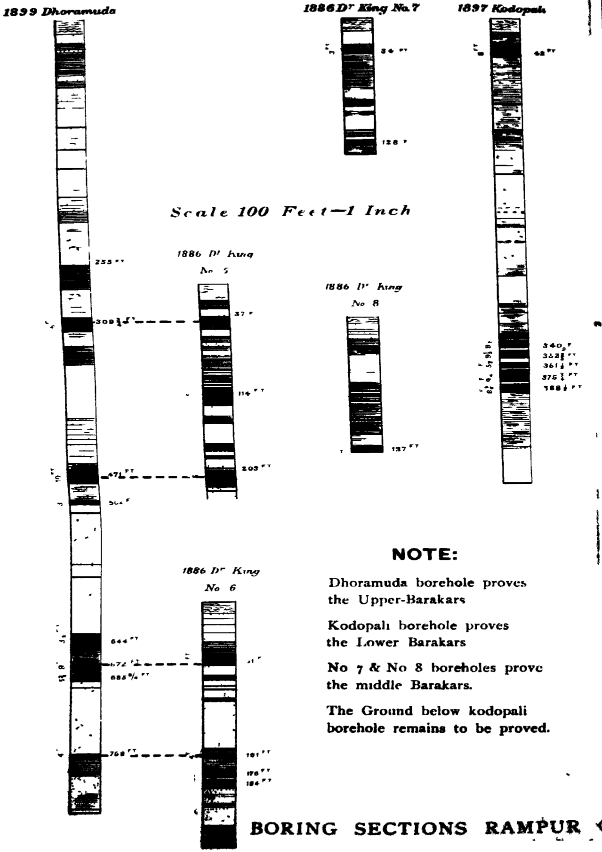
SHOWING SECTION OF STRATA NEAR THE EEB RIVER.

Note: Conglomerate lies unconformably upon the white sandstone.

GEOLOGICAL SURVEY OF INDIA

G. F. Reader.

SHOWING SUPPOSED CORRELATION OF DHORAMUDA & DR. KING'S NOS. 5 & 6 BOREHOLES



NOTE:

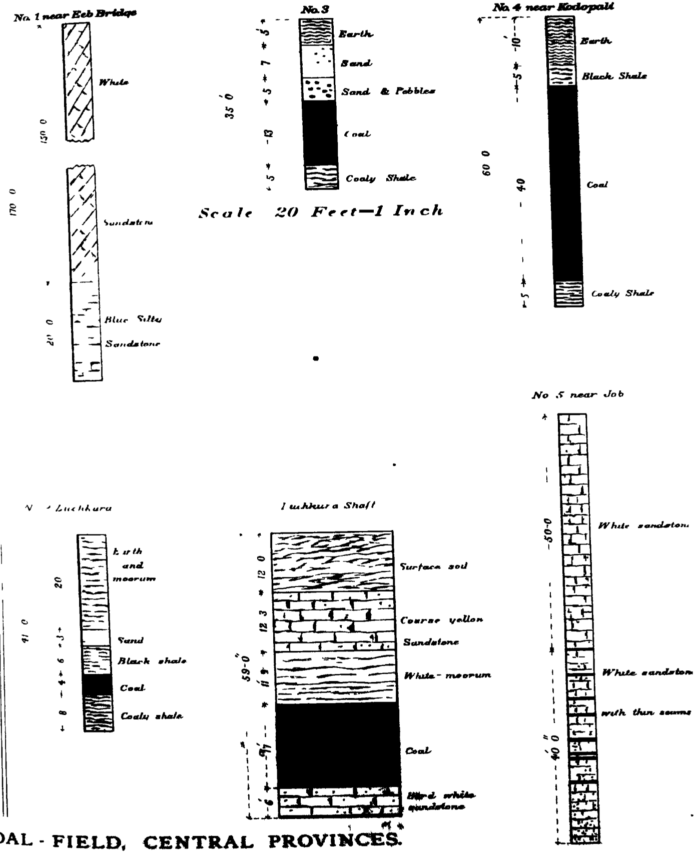
Dhoramuda borehole proves the Upper-Barakars

Kodopali borehole proves the Lower Barakars

No 7 & No 8 boreholes prove the middle Barakars.

The Ground below kodopali borehole remains to be proved.

BOREHOLES PUT DOWN BY THE BENGAL NAGPUR RAILWAY COMPANY.



BORING SECTIONS RAMPUR COAL-FIELD, CENTRAL PROVINCES.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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GEOLOGICAL SURVEY OF INDIA.

VOL. XXXII, PART 3.

NOTES ON THE "EXOTIC BLOCKS" OF MALLA JOHAR IN THE BHOT MAHALS OF KUMAON, *by* A. VON KRAFFT, PH.D., *Assistant Superintendent, Geological Survey of India.*

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

NOTES ON THE "EXOTIC BLOCKS" OF MALLA JOHAR IN THE BHOT MAHALS OF KUMAON, *by* A. VON KRAFFT, PH.D.,[1] *Assistant Superintendent, Geological Survey of India.*

I.—INTRODUCTION.

In 1892 Messrs Griesbach, Diener and Middlemiss discovered near Chirchun[2] in Hundés and in the upper Kiogarh valley (Malla Johar) isolated limestone blocks with permo-carboniferous and triassic fossils These blocks which are situated within a synclinal belt of Spiti shales and flysch and are connected with igneous rocks, were compared to the "Klippen" of Europe.

Griesbach[3] and Diener[4] have given accounts of their observations with geological maps. The latter author left the "Klippen" at first unexplained, while Mr. Griesbach believed them to be due to faulting, accompanied by intrusions of igneous rocks. Later on the permo-carboniferous and muschelkalk fossils collected were described by

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[1] Died at Calcutta on the 22nd September 1901.

[2] I prefer this spelling to that of the Indian Trigonometrical Survey map ("Chitichun") seeing that the name is pronounced "Chirchun" by the natives of Milam. Strachey in his geological map of Kumaon, Garhwal, and the adjoining parts of Hundés also spells the locality "Chirchun." Quart Journ. Geol. Soc., VII, 1851, pl. XVI.

[3] "*Notes on the Central Himalayas.*" Rec. Geol. Surv. Ind., Vol. XXVI, pt. 1, 1893, pp. 19 to 25.

[4] "*Ergebnisse einer geologischen Expedition in den Centralen Himalaya.*" Denkschriften d. k. Akad. d. Wissensch. Wien 1895, pp. 588 to 607.

Diener.[1] In a more recent paper Diener[3] elaborately discussed the relation of the Himalayan "Klippen" to those of Europe. He comes to the conclusion that the former differ from all European occurrences by some remarkable features, the most pronounced being their connection with igneous rocks Nor can, in his opinion, any of the theories advanced with respect to the European "Klippen" be applied to them. Diener inclines to the belief that the most plausible explanation is that given by Griesbach in the paper quoted

In spite of the undoubted interest of these occurrences, seven years elapsed ere another geologist entered the Chirchun area. My colleague Dr. Walker was sent there in 1899. Unfortunately ill-health forced him to return in a very short time, but not before he had obtained a very good collection of permo-carboniferous fossils from the Peak Chirchun No. 1. These are now being examined by Professor Diener.

In 1900 I was ordered to Chirchun, but an unexpected obstacle intervened. My plan of crossing by the Langpaia Lek into Hundés was frustrated by orders from the Local Government, strictly prohibiting me from entering Tibet. Acting on instructions from headquarters then received, I proceeded to Laptal in Malla Johar, which is British territory.

This area had been visited years ago by Mr. Griesbach (see pp. 80, 81, 149, and 155 in Mem XXIII). He noticed the presence of "basaltic traps, associated with serpentinous masses" which he considered to be intruded into the cretaceous series flysch), remarking that some of the traps might be contemporaneous. He believes the igneous rocks "form part of the younger eruptive rocks which are largely represented in eastern Hundés, and to which probably a middle tertiary age must be assigned."

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[1] *The Permo-carboniferous fauna of Chitichun, No. 1.*" Pal. Ind., Ser. XV, Vol. I, pt. 3.

[2] "*The Cephalopoda of the Triassic limestone crags of Chitichun.*" Pal. Ind., Ser. XV, Vol. II, pt. 3.

See also *Jovites*, nov. f. ind. ex aff. *J. bosnensis* in *E v.* Mojsisovics. "*Upper Triassic Cephalopoda fauna of the Himalaya.*" Pal. Ind, Ser. XV, Vol. III, pt. 1, p. 18, plate IX, figs. 4, 5.

[3] "*Notes on the Geological Structure of the Chitichun region.*" Mem Geol. Surv. Ind., Vol. XXVIII, pt. 1, pp. 1 to 27.

Mr. Griesbach considered the light grey and white limestones occurring near the Balchdhura pass to be a higher division of the cretaceous series, equivalent to Stoliczka's Chikkim limestone.

The ground was again visited by the expedition of 1892. On their way to Chirchun, the three geologists passed through the Kiogarh valley, but being still unaware of the complicated structure of the neighbouring Chirchun area, they shared the view originally expressed by Griesbach with respect to the light grey limestones of the Kiogarh peaks. Subsequently, suspecting that these limestones might possibly represent exotic blocks they revisited Malla Johar. Their doubts were justified, for Mr. Griesbach discovered near Talla Sangcha E.G [1] a loose block of a red and white limestone with *Jovites n f. ex aff. J. bosnensis*, E. v. Mojs., which, according to Mojsisovics, proves the block to belong to the carnic stage of the upper trias.

Diener gave a short description of the neighbourhood of Malla Sangcha, which is in extract as follows:—

The base of the most western limestone peak is made up of Gieumal sandstones which show a very complicated dip and are penetrated by numerous veins of intrusive rocks. In the upper portion of the mountain these igneous rocks and the "tufa" associated with them predominate. The limestone mass itself rests entirely on beds of a clearly igneous character, without coming into contact with the sandstone formation.

The highest "crag" forms a steep scarp and is likewise traversed by veins of a diabase porphyrite. The limestone is of a white and reddish white colour without any distinct stratification, semicrystalline and partially altered, especially so where surrounded by intrusions of igneous rocks. No fossils were found *in situ* in the limestone. The block with *Jovites* found by Mr. Griesbach is a red marble, apparently detached from the main mass of the limestone peak and exactly similar to some of the famous red Hallstatt marbles from the Salzkammergut in upper Austria and Styria. This facies differs widely from that of the carnic beds in the main region of the triassic belt of the Central Himalayas. From the presence of the genus *Jovites* in the limestone block found to the east of Talla Sangcha it results that the huge masses of limestone between the Balchdhura and Kiogarh-Chaldu passes cannot rest in a normal position on the flysch. Considering the great thickness of the limestone cap, Diener is inclined to suppose that the peak is composed of sediments belonging to very different geological periods, as is the case in the range of Chirchun No. 1, the carnic stage forming only part of the limestones. These stand in a similar structural relation to the flysch forming their base, as the limestones of the Chirchun area do to the Spiti shales.

---

[1] E. G. throughout this paper stands for "encamping ground."

During the months of July and August 1900 I spent six weeks in this frontier district and found it to abound with exotic blocks, and in a few of these I discovered numerous fossils, chiefly ammonites. I have also obtained geological observations important enough to allow of an attempt to explain the origin of the blocks being made. The conclusion at which I arrived, is that the exotic blocks were brought up to the surface by violent volcanic outbursts, later disturbances having thrust the whole into confusion. At the same time, however, it became evident that nothing but a detailed examination of the whole block-bearing area would lead to definite results.

Area examined. Physical features.

The area worked[1] out is situated at the head of the Kiogarh river, a tributary of the Girthi river, which runs from east-south-east into the Dhauli river, near Malari. To the north, east and south-east the area is bordered by a high range, which forms two half circles, connected by the Kiogarh high plateau. The range represents part of the great watershed between the tributaries of the Sutlej and the Ganges, and at the same time forms the boundary between British territory and Hundés.

The northern semicircle opens towards the west near Talla

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[1] See Geological Map, pl 14.

Sangcha on to rolling plateaus, covered with Spiti shalès, which extend far to the west and north-west. The southern half circle is shut off to the west by an anticline of triasso-jurassic limestones with a north to south strike. Both half circles are drained by branches of the Kiogarh river, meeting in a ravine that traverses the northern termination of the anticline just mentiond halfway between Talla Sangcha and Laptal E. Gs. From the northern half circle the Balchdhura Pass, 17,590′, leads into Hundés (road to Chilumkurkur) and the southern one is connected with that country by three practicable passes, *viz.*, a nameless pass between Kiogarh No 3 and No 4 approximately 18,000′, the Kiogarh-Chaldu pass, 17,440′, and the Kiogarh-Chirchun pass, 17,960′ (road to Chirchun E. G)

The average height of the district is very considerable, the lowest point (near junction between the two main branches of the Kiogarh river) being approximately 13,000′, the greatest vertical elevations rising up to more than 19,000′. At no point is the boundary range as low as 17,000′.

The striking contrast in the configuration of the landscape seen everywhere along the great Himalayan watershed is of course conspicuous in this area. To the north, speaking generally, the country descends slowly to an undulating high plateau, while the land south of the watershed is deeply eroded into steep bold cliffs and narrow gorges. My work lay on this side of the watershed where there are much better sections than in the Chirchun area, which forms part of the Tibetan high plateau

Probable extent of the block-bearing area.

The extent of the whole block-bearing area cannot be deliminated in detail We know from the researches of the expedition of 1892 that it reaches south as far as Kungribingri, 19,170′, and east beyond the Chaldu river. But how far it extends to the north can so far only be guessed at. At any rate it includes the Peaks Ghátámémin, 18,700′, and Sami, 17,920′, of the Indian Trigonometrical Survey map. From the frontier I could see that exotic blocks occur several miles to the north of Balchdhura No. 2 Exotic blocks may also occur to the north of the Niti pass,[1] and it is not impossible that they are connected by intermediate occurrences with those of Johar and Chirchun.

II.—STRATIGRAPHICAL FEATURES.

Within the area represented on the geological map attached to this paper, the following stratigraphical divisions occur, which are in descending order :—

4. Shales, sandstones, etc., upper flysch, 800 to 1,000 feet. } *Cretaceous.*
3. Greenish grey sandstone, "Gieumal sandstone," Stol., lower flysch . . . . . 400 to 500 feet. }
2. Spiti shales. Upper jurassic to lowest cretaceous.
1. Grey limestones, ranging from upper trias (dachsteinkalk) into the middle jurassic

Triasso-jurassic limestone series.—The lowest division is chiefly composed of bedded limestones with some massive layers. The limestones being throughout poor in fossils, no subdivision is possible. From their lower portion *Megalodon* and other upper triassic fossils are recorded, while the topmost 300 to 400 feet are proved by fossil contents to be of middle jurassic age, but no reliable palæontological evidence is available pointing to either lias or rhætic, although the perfect conformity prevailing leaves no doubt that sedimentation has continued without interruption from upper triassic until middle jurassic times.

The evidence regarding the middle jurassic portion of this limestone mass is twofold. Professor Diener[2] collected at two localities (Shalshal cliff in Painkhanda and Chanambaniali peaks in Hundés) from the topmost layer, which is made up of red iron pisolites,[3] a number of fossils, which were examined by Dr. F. Suess. The fauna consists of a few cephalopoda, brachiopoda and numerous *Belemnites* (*B. sulcacutus*, F. Suess) and is according to F. Suess of middle jurassic age, probably Kelloway.

I myself discovered in Spiti in a section near Gieumal, 350 to 400 feet below the Spiti shales, a well-preserved ammonite, which is very closely allied to, if not identical with, *Stephanocerus coronatum*, Brug.). a species also characteristic of the Kelloway. We may therefore conclude that at the very least 400 feet of the limestone mass in question, but probably a still greater thickness, belongs to the middle jurassic.

---

[1] Mr. Griesbach (Mem. XXIII, p. 83) noticed there grey limestones, which he correlated with the Chikkim limestone. As the latter is not developed in Johar, it appears possible that the limestones of the Niti pass represent exotic blocks, all the more so as igneous rocks are reported from the same area.

[2] Ergebnisse, l. c., pp. 584 to 586.

[3] This bed was described by Griesbach (Mem. XXIII) as lias.

Spiti shales.—The Spiti shales have been subdivided by Mr. Griesbach[1] into three divisions, which have also been adopted by Dr. Diener. As to the fauna no details are yet available as the description of the fossils, which has been entrusted to Prof. Uhlig, is not yet concluded. The main results are however contained in some preliminary remarks published by Diener[2] and are as follows :—

(3) Upper Spiti shales, "Lochambel beds," Diener, most probably representing Berriasian, but possibly with affinities to Tithonian and Valanginian.

(2) Middle Spiti shales, "Chidamu beds," Diener, full of concretions containing ammonites. Upper jurassic, probably Kimmeridge.

(1) Lower Spiti shales, full of *Belemnites gerardi*, upper jurassic.

Gieumal sandstone.—The Spiti shales pass gradually into the overlying Gieumal sandstone, which therefore is proved to be of cretaceous age, in spite of the want of characteristic fossils.

Before describing the cretaceous series in detail it will be well to point out that there is a considerable lithological difference between the cretaceous of Spiti and that of Johar. In Spiti calcareous bands with fossils are met with in the Gieumal sandstone, which is overlaid by a white limestone ("Chikkim limestone," Stol.) and calcareous shales ("Chikkim shales," Stol.), whereas the cretaceous of Johar contains but an inconsiderable admixture of calcareous deposits. It is almost solely composed of sandstones and shales and bears a marked similarity to the European flysch.

Upper Flysch.—In the upper flysch the following lithological divisions[3] can be distinguished (in descending order) :—

4.	*b* Red tuffs	thin bedded	50′
	a Green tuffs		150′

---

[1] Memoirs XXIII.

[2] *Loc. cit.*

[3] Compare plates 1 and 4.

4*e*. Greenish and grey sandstones, alternating with shales. Pass through green tuffaceous sandstones upwards into 4*f*	300′
4*d*. Hard, black, siliceous shales, passing through crumbling shales into 4*e*	30′ to 40′
4*c*. Brown weathering sandstones, alternating with shales	10′
4*b*. Black, crumbling shales	200′ to 300′
4*a*. Red and greenish shales and red shaly limestones	app. 100′
3. Gieumal sandstones	400′ to 500′

The Gieumal sandstone becomes shaly in its uppermost layers, weathering into long, pencil-shaped fragments. Above this follows —

4*a*. Near the base siliceous red shales of an intense terracotta colour intercalated with a few bands of red hornstone and splintery greenish shales. Higher up the shales become calcareous and earthy, and thin bands of dense, somewhat siliceous, greenish grey limestones appear.

This series is very conspicuous from a distance, especially so on the hills to the north of Talla Sangcha E. G. No doubt it corresponds to the "dense red earthy beds" mentioned by Griesbach[1] from the flysch of the Chirchun area.

4*b*. consists of black, crumbling alum shales, very similar to the Spiti shales, but with some peculiar characteristics, such as the occurrence of flaggy, brown weathering limestones with many calcspar veins and of large, ferruginous concretions. A negative feature consists in the entire absence of fossils beyond plant remains frequently found in the flaggy limestones. This division was also recognized by Mr. Griesbach in the Chirchun area [1] and its resemblance to the Spiti shales was pointed out, a few traces of *belemnites* being mentioned. Its thickness cannot be accurately determined owing to the disturbances it has undergone.

4*c*. is a grey, reddish brown weathering, micaceous, somewhat gritty sandstone in a few thick layers with shaly partings.

4*d*. Hard black, siliceous shales, weathering rusty brown, traversed by cleavage planes which produce cubical fragments. These shales are best seen on the southern slope of the Balchdhura heights, and in an overfold to the south of Kiogarh Chirchun E. G. (plates 1 and 4).

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[1] Records, *l. c.*, p. 21.

This group passes through a small thickness of black, crumbling shales into—

4*e*. consisting of grey and greenish sandstone with very thin, mostly brown shaly layers. A few calcareous bands are intercalated near the base. This series is very similar to the Gieumal sandstones but can be distinguished from them by its abundance of fucoids and indistinct plant remains. The sandstones gradually become tuffaceous higher up and pass into

4*f*. a series of very thin-bedded green tuffs (150') overlaid by a small thickness of red tuffs. The former may be identical with "a hard rock, generally bluish green in colour, which probably has been formed to a large extent of trappean material," which was observed by Mr. Griesbach in the Chirchun area.

Age of upper Flysch.—The upper flysch is throughout devoid of fossils that might afford any clue as to the age of the various divisions, and although there can be no doubt that most of them are cretaceous, the question arises, whether the topmost beds do not extend into the nummulitics or not.

It will be more convenient to deal with this question after having described the area in full, and it may suffice to remark here that most probably the nummulitics are not included in the upper flysch.[1] As to the arguments which lead to this conclusion, I may refer the reader to the last chapter of this Memoir.

III.—GENERAL CHARACTERS OF THE IGNEOUS ROCKS AND EXOTIC BLOCKS.

Along the boundary range from Balchdhura No. 2 to the Kiogarh-Chaldu pass and in the vicinity of the Kiogarh-Chirchun pass the flysch is overlaid by great masses of basic igneous rocks, which include a large number of "exotic blocks", consisting chiefly of limestones, the whole resembling in appearance an extraordinarily coarse breccia without any trace of stratification. In describing these masses it will be convenient to deal first with the igneous rocks and subsequently with the exotic blocks, imbedded in the former.

---

[1] The view here adopted differs from that expressed in General Report, 1900-01, which was published before the present Memoir had been concluded.

(*a*) The igneous rocks.

Rocks of igneous origin occur, as mentioned above, in the flysch, the youngest division consisting of subaqueous red and green tuffs.

These have, however, nothing to do with the subaerial basic igneous rocks we have to consider at present.

A number of rock specimens brought back were kindly determined by Mr. T. H. Holland, who provided me with the following short notes :—

Petrological evidence.—Most of the rocks present the characters of lava flows, generally basic in composition, but too much altered for precise determination, and many of these can be referred to as andesites. They have generally a pilotaxitic structure, but their ferromagnesian silicates having been altered beyond recognition, they may as often be related to the diabases as to the andesites: the distinction is not important. Many are distinctly amygdaloidal, but in some the cavities now filled in with calcite may have been the result of secondary alterations.[1] Other specimens are spherulitic pitchstones which fall into line with the amygdaloidal and other structures which indicate a volcanic (surface) origin for most of the rocks. One rock is a serpentine, which has resulted from the alteration of a peridotite.

Aspect in the field.—In Johar one generally meets with loose débris, consisting of large and small blocks of green and red andesite and finer volcanic material, mixed with a multitude of pieces of sedimentary rocks. I was for some time in doubt as to whether this does not represent a volcanic agglomerate. Especially the southern slope of the Balchdhura heights where no outcrop of solid rock is seen such an explanation might appear correct, and I met with occurrences reminding me of volcanic bombs. Round balls of amygdaloidal andesite, approximately 2 feet in diameter, on being broken up, were found to contain calcite kernels, large in the centre, and decreasing in size towards the periphery. At the same locality I observed blocks of coarse breccias composed of green andesite and red limestone pieces.

---

[1] A rock specimen collected by Diener near Talla Sangcha was examined by C.V. John, and his notes are communciated in Diener, "Ergebnisse," p. 599. V. John described this rock as an amygdaloidal diabase. It appears to represent a type of near affinity to those of my own collection which Mr. Holland determined as amygdaloidal andesites (see above).

I do not, however, now believe that true agglomerates are anywhere existent in Johar. The same loose débris, such as is met with at the Balchdhura heights, is also found in many other places, where it is obviously produced by the weathering of lavas in which a large number of foreign fragments are involved. These curious lavas are, for instance, *in situ* round the base of the Kiogarh plateau. It thus appears certain that the loose masses alluded to represent débris from lavas, not volcanic agglomerates. The round balls of andesite described above can well be brought into accord with this explanation. In two places I observed a sphæroidal or sack-like structure in solid lavas, no doubt the result of weathering. To this sphæroidal weathering we may attribute the bomb-like balls. This is the better justified by the solid crust generally seen in true volcanic bombs, being wanting. Finally, as regards the breccias composed of andesite and red limestone, found at the Balchdhura heights, they also accompany the lavas, and are *in situ*. North of the Kiogarh-Chaldu pass and to the south-east of Kiogarh-Chirchun pass breccias were met with in close connection with the sphæroidal lavas just mentioned.

Fragmental rocks.—A few remarks as to the fragmental rocks occurring occasionally among the lavas may be added. The breccia found north of the Kiogarh-Chaldu pass is of a peculiar character. The fragments according to Mr. Holland are chiefly altered pitchstone, probably andesitic in composition, others are serpentine. The narrow interstices between the fragments are filled up by densely red limestone of a laminated structure, the laminae being parallel to the surfaces of the pitchstone fragments. It appears that in the original limestone, fragments were crushed together with the harder volcanic rocks, with the result that the limestone now apparently forms the cement of the breccia. Volcanic tuffs are often met with but never in a fresh condition. A specimen of tuff was found by Mr. Holland to contain fragments of various derivation, including quartzites and volcanic rocks.

Age of volcanics.—The volcanic rocks of Johar are younger than the flysch. This follows first from their overlying the latter and secondly from the fact that blocks, derived from various divisions of the flysch series, even the tuffs (*4f*) are met with among the volcanics. The latter must be considered equivalent in age to the volcanics of the Indus valley, *viz.*, lower tertiary.

Origin.—As to their mode of origin they are clearly subaerial This must be concluded from their petrological and geological features, and from the absence of all proof of a subaqueous origin. The volcanics show no trace of bedding, the fragmental constituents are angular, never rolled, and no sedimentary deposits are connected with them.

As stated in the introduction, these rocks were previously considered intrusive rocks, a theory which can no longer be maintained. Distribution and petrological habitus clearly indicate their surface origin, and this is further corroborated by their being folded together with the flysch under conditions which exactly recall sedimentary beds. There must of course be volcanic vents and dykes, through which the igneous rocks have reached the surface, but the sources of discharge no doubt lie outside Johar, *viz.*, to the north or north-east of it within Hundés, as nowhere in the area examined have intrusive dykes been discovered.[1] It is true that in places volcanics are mixed up with the flysch, but this can in almost every instance be proved to be the result of later disturbances.

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[1] I have twice followed the route along which Diener ascended from Talla Sangcha towards Kiogarh No. 1, but completely failed to discover the "numerous veins of intrusive rocks" which Diener reported. Nor have I observed intrusions anywhere else in the flysch of Johar, although I examined this district much more closely than any previous observer.

There is, however, another subordinate mode of occurrence of igneous rocks to be considered. In many of the limestone blocks thin igneous veins, traversing the blocks from end to end, are to be seen. These are instances of true intrusions. Wherever these veins are present the limestones are much altered and marmorised. As a rule ten or more veins are seen running parallel to each other at regular intervals, a feature which is probably due to their following bedding planes. Twice I met blocks with intrusions, which evidently have been plicated, for they described narrow angles.

The igneous rocks thus intruded resemble in macroscopic appearance those surrounding the blocks.

The explanation of these intrusive veins affords no difficulty. They must have been formed while the limestones were still *in situ*, although they had then already been acted upon by the igneous rocks. Most likely therefore these limestones are derived from volcanic necks and thus resemble in origin the volcanic blocks mentioned above.

(*b*) The exotic blocks.

Exotic blocks abound to such an extent that the number of those exceeding 10 feet in diameter alone must be calculated to be many hundreds while the smaller blocks are quite innumerable. The volcanics of the Kiogarh high plateau especially are extremely rich in exotic blocks. It would therefore be impossible to mark on the map even the larger blocks separately. The course I followed was to indicate those only which were found in any way remarkable, either by their fossil contents, conspicuous forms, isolated position, etc. Accumulations of large blocks, which contain little volcanic material—such as occur in the Kiogarh heights (for instance Kiogarh No. 3)—were marked as single limestone masses. The rest were left unmapped.

The exotic blocks are of various lithological descriptions. Most of them are grey or red limestones, but in places sandstone blocks are common. Rarer types are blocks consisting of tuffs and shales.

But these blocks being of sedimentary origin, lithological characters are of small importance compared with the question as to which stratigraphical horizon they represent. This could of course only be satisfactorily ascertained were fossils from many of them available. I need hardly say that this is not so; indeed by far the greater part is entirely unfossiliferous, and this cannot be wondered at, seeing that they are imbedded in igneous rocks and have in ninety-nine cases out of a hundred been highly altered. It was only by examining many hundreds of blocks that I was able to obtain fossils here and there. Weeks of unsuccessful search were thus now and then only interrupted by a fortunate find. But in most cases, when once discovered, the fossils were to be had in large numbers. Other blocks could be determined with more or less certainty by their lithological characters, and thus I obtained evidence of the representation of several horizons, one being palæozoic, the others mesozoic. Some of these horizons are identical with those found in the exotic blocks of the Chirchun area, but most of them are new. They are:

1. Permo-carboniferous (E. Blocks 9, 11, 12, 13, 15, 18, 19 (?) on map). Blocks of this age were chiefly traced in the hills to the north-west and west of the Kiogarh-Chirchun pass. A loose block containing fossils of that age was observed in the neighbourhood of Malla Sangcha E. G. and had no doubt rolled down from the higher slopes of Kiogarh No. 1.

Lithologically the permo-carboniferous limestone may be described as a massive, light grey and red, marble-like crinoid-limestone with many cleavage planes. Large sections of crinoid stems (app. ½ inch in diameter) form a most characteristic feature. Blocks of this age rarely exceed 30′ to 50′ in diameter, E. B. 9 alone being of larger dimensions [1] (at least 300 cubic feet). Whereas on Peak Chirchun No. 1, which is composed of limestone of this age, fossils abound, the permo-carboniferous blocks found in Johar are very poor in fossils. The only locality which yielded a larger number of specimens is E. B. 9, but here also several days' search was required to obtain satisfactory collections. The fauna is identical with that described by Diener from Peak Chirchun No. 1, as is proved by the following list of fossils, kindly communicated by Prof. Diener :—

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[1] See Pl. 4.

Productus abichi, Waag.
,, *gratiosus* ,,
,, *chitichunensis*, Dien.
Marginifera typica, Waag.
Enteletes, sp. ind.
Uncinulus timorensis, Beyr
Hemiptychina himalayensis, Dien.
Camorophoria purdoni, Dien.
Spirifer wynnei, Waag.
,, *tibetanus*, Dien.
Martinia, *dis.* sp.
Lyttonia sp ind.
Spirigera royssii, Lev.

2. *Lower trias* (E. B. 20 on map). One large block was discovered with numerous cephalopoda of lower triassic age, situated about 1½ miles to the north of Kungribingri No. 2 at the right angle formed where the boundary range turns from a south to north direction to the east.

The rock is of a dark red, earthy limestone, thin bedded, with a few grey layers. The cephalopoda are mostly of indifferent preservation being filled by calcite. Most of the fauna collected belong to the genera *Flemingites* and *Danubites*, two very characteristic genera of the Himalayan lower trias (horizon of *Flemingites rohilla*). A common species is *Danubites nivalis*, Dien. Other genera represented are *Meekoceras*, *Hedenstroemia*, *Prosphingites* and a genus similar to *Pseudosageceras*, Dien. This fauna awaits further examination.[1]

Lower triassic blocks are not recorded from the Chirchun area.

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[1] The Meekocerata were recognised to contain species unknown from the horizon of *Flemingites rohilla* of the Himalayan series, while the species common to the latter are wanting in E. B. 20. This points to faunistical peculiarities being present, yet I have little doubt that they are of small importance.

3. Lower Muschelkalk (?). On the southern slope of the Balchdhura heights I found a loose block with a few fragmentary and badly preserved ammonites. One of these shows ceratitic sutures, another is in transverse section and sculpture similar to *Procladiscites jasoni*, Dien. This block may be of lower muschelkalk age and equivalent to the lower muschelkalk horizon discovered by Middlemiss in the Chirchun area.[1] The state of preservation of the fossils excludes any definite statement.

4. Ladinic or Lower Carnic stage (E. B. 1 on map, pl. 1, and section 1 on pl. 12). Somewhat below E. B. I found several loose specimens of dark red, very ferruginous limestone with *Daonella indica*, Bitt. As these fragments are lithologically identical with E. B. 1, the fossils must have come from it.

The specimens are of large size, like fig. 11 on pl. vii in Bittner's Memoir on the Brachiopoda and Bivalves of the Himalayan Trias.[2] E. B. 1 consists of thin-bedded limestones, alternating with very thin bands of dark red shales and differs from any other I met with. *Daonella indica* was previously assigned exclusively to the lower carnic stage ("Traumatocrinus limestone" of the Shalshal cliff section with *Joannites cymbiformis*) but has been found subsequently in Spiti and in Painkhanda in the ladinic stage of the muschelkalk too. E. B. 1 may therefore represent either of these horizons.

Blocks with *Daonella indica* are not recorded from the Chirchun area.

5. Upper Carnic stage (E. B. 2 on map, section 1 on pl. 12 and pl. 3). About one mile to the north-west of the Balchdhura pass at approximately 18,000 ft. a block was discovered, the richest in fossils and at the same time the least influenced by igneous rocks of any I observed. It is a marble like that of the famous Hallstatt beds of the eastern Alps, bright red, massive, and not in the least earthy.

A very large and well preserved collection of *ammonites* with a few *bivalves* and *brachiopoda* was obtained from this block I have so far identified the following three species with forms described from the Himalayan "Daonella beds":—

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[1] Pal. Ind., Ser. XV, vol II, pt. 3.

[2] Pal. Ind., Ser. XV, vol. III, pt. 2.

Cladiscites subaratus, v Mojs.
Phylloceras ebneri ,, ,,
Juvavites (griesbachites) medleyanus.[1]

The commonest genus of the fauna is *Cladiscites*, a species belonging to the group of *Cladiscites tornatus* being the leading fossil.

Other genera are: *Tropites*, *Arcestes*, *Placites*, *Jovites*, *Nautilus*, etc. Of the rare *Tropites*, species resembling *T. subbullatus*, *T. acutangulus*, *T. barthi*, and *T. spinosus*, v. Mojs, occur.

This fauna also awaits detailed examination.

There can be no doubt that it represents the Tropites horizon of the carnic stage, being equivalent to the "Subbullatus beds" of the Alps and the Tropites limestone of Spiti and Byans

The loose block with *Jovites n. f.* ind. ex. aff. *J. bosnensis* found by Mr. Griesbach near Talla Sangcha E. G., belongs to this horizon, this species being also present in my collections from E. B 2.

Carnic blocks are not recorded from the Chirchun area

6. *Dachsteinkalk* (?) Exotic block 8 (pl. 7) and Kiogarh high plateau (plates 2 and 3). The predominant rock of the exotic masses is a light grey, dolomitic massive limestone. Its main distribution is in the mountains between the Balchdhura and Kiogarh-Chaldu passes (Kiogarh high plateau), but blocks of light grey, dolomitic limestone were also found elsewhere.

Unfortunately not even a trace of a fossil was observed, but it is probable that the limestones represent chiefly the Dachsteinkalk.

Grey limestone blocks are also recorded from the Chirchun area; Griesbach and Diener likewise consider them Dachsteinkalk.

7. *Lower Lias* (E. Bs. 4, 6, 7, 16, 17 on map, plates 3 and 8). No

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[1] This species of hitherto doubtful geological position I found recently in the topmost "Daonella beds" of the Bambanag cliff, immediately below the "Hauerites beds," Diener.

doubt the most interesting of all the blocks are those of lower liassic age. Five belonging to this horizon were observed, of which two (16 and 17) have yielded a considerable number of lower liassic ammonites. These are situated about 1¼ mile west-north-west of the Kiogarh-Chirchun pass and the other three, poorer in fossils, 4, 6, 7, lie near Malla Kiogarh E. G. The rock is a very earthy, brick red, rather thin-bedded, nodular limestone, with a few thick grey layers. This type of block is the most characteristic of all, and when once closely observed can be recognized from afar by its characteristic tint.

The fauna, containing as it does several species of *Arietites*, is of an unmistakable lower liassic type. The commonest genus of the fauna is *Phylloceras*.

This is the first record of lias fossils being found in India.

It is of particular interest that the facies is the Alpine one. My specimens are in preservation identical with the lias of Adneth near Salzburg (Austria).

8. Spiti shales (?) } Balchdhura heights.[1]
9. Gieumal sandstone (?) }

The Balchdhura heights are made up of masses of unfossiliferous shales and sandstones. The sandstones are lithologically indistinguishable from the Gieumal sandstone, and the shales associated with them are black alum shales. I believe that these masses represent Gieumal sandstone and Spiti shales; as fucoids are wanting in the sandstones, we have no reason to correlate them with the upper flysch sandstones (4*e*). There only remains the Gieumal sandstone with which to compare them. Accordingly we may consider the shales to be Spiti shales, *viz.*, the uppermost division, which in the normal sections alternates with the Gieumal sandstone.

Sandstone blocks, all apparently Gieumal sandstone, are common throughout the exotic masses, but nowhere do they dominate so much as in the Balchdhura heights.

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[1] Pl. 1 and section 1 on pl. 12.

10 Upper Flysch Sub-Division 4b. (E. Bs. 3, 14 on map). Within the igneous rocks south of the Balchdhura pass, I observed a block consisting of thin-bedded brown limestones, with shaly partings which could at once be recognized as belonging to sub-division 4*b* of the upper flysch.

On the heights south of the Kiogarh plateau, between E. Bs. 13 and 15, black shales of the same sub-division, with ferruginous concretions and brown weathering flaggy limestones occur.

11. Upper Flysch Sub-Division (*4f*). Green tuffs, representing sub-division 4*f*, were observed in the igneous rocks of the Balchdhura heights close to E. B. 1. This occurrence had to be left out on the map.

The last mentioned four horizons are not recorded from the Chirchun area.

In conclusion I must remark that among the very numerous unfossiliferous limestones there are many of a red colour, resembling the Tropites limestone. Most of the blocks offer no clue whatever to their age.

Origin of red and grey limestone blocks.—Leaving the four youngest horizons (Spiti shales and flysch) out of consideration, we will now deal in some detail with the older horizons up to the lias. We must of course presuppose that the blocks, found within the volcanics of Johar, originally formed part of one and the same series at some distance from their present place of occurrence. This theoretical series we may call the " Tibetan Series[1]," as it must needs be *in situ* somewhere in Tibet, and we may compare it first with the corresponding beds observed in the normal sections of the Himalayas.

" Tibetan Series."

Comparison with "Himalayan Series."—The comparison leads to the conclusion that each single sub-division of the Tibetan series known so far, from the permo-carboniferous up to the lias, differs from the corresponding Himalayan division.

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[1] I mean to restrict this term to the sequence from the permo-carboniferous up to the lias, which differs in facies from what is seen in the Central Himalayas.

Permo-carboniferous.—As regards this system, there is no sequence of beds known in the Himalayas which could be compared either palæontologically or lithologically with the red and white limestones of the exotic blocks. In most of the sections of the younger palæozoics of the Himalayas there is a marked unconformity at the base of the Permian Productus shales,[1] and this would lead to the conclusion that the permo-carboniferous is wanting. There is only one section known in which the gap appears to the filled up (Lio in Spiti), but this section has not yet been worked out in full detail. But even supposing faunistical equivalents to the permo-carboniferous should be discovered there, their lithological equivalents are undoubtedly absent as the series in question consists of conglomerates, sandstones, shales and grey limestones.[2]

Lower Trias.—The lower trias of the Tibetan series appears to be the exact equivalent to the "horizon of *Flemingites rohilla*"[3] of the Himalayan series. There appear to be certain faunistical peculiarities, but as far as I can judge they are of no great importance. Lithologically, however, there is a very marked difference, the horizon being in the Himalayan series represented by grey or black limestones with intercalated bands of black shales.

Lower Muschelkalk.—As regards the lower muschelkalk, the case is much the same as with the lower trias. The fauna, which was described by Diener from red limestone blocks near Peak Chirchun No. 1 (Middlemiss crag) occurs in the Central Himalayas in grey limestones with *Spiriferina stracheyi* below the horizon of *Ceratites thuillieri*.[4]

Ladinic or lower Carnic stage.—Beds with *Daonella indica* occur in the Himalayan series in the ladinic stage as well as in the lower carnic stage, but their facies is of a dark, mostly black and shaly limestone and therefore differs widely from that of the equivalent division of the Tibetan series.

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[1] See Griesbach, Mem XXIII, p. 65; Hayden, General Report, 1899-1900, p. 187. In Spiti the unconformity occurs at the base of a calcareous sandstone, underlying the Productus shales.

[2] Hayden, General Report, 1899-1900, p. 188.

[3] This new term I introduced to replace the term "Subrobustus beds," Diener, *Ceratites subrobustus* having been proved to belong to the lower muschelkalk.

[4] General Report, 1899-1900, p. 205, and 1900-1901, p. 26.

Upper Carnic stage.—The *Tropites* horizon of the Himalayan series is developed in Spiti as a grey, brown weathering somewhat shaly, nodular limestone with few, badly preserved ammonites.[1] At the Bambanag cliff, where this horizon has only recently been discovered by myself,[2] it is a grey, shaly limestone alternating with grey shales, which belong to the topmost "Daonella beds" These limestones of the Bambanag cliff also differ faunistically from the Himalayan and Tibetan Tropites horizon by the apparent absence of the genus *Tropites* and the general paucity of cephalopoda. In Byans, the Tropites horizon is represented by grey limestones including a rich and well preserved fauna of cephalopoda, among which *Tropites* is found. The fauna appears to be very much richer than that of Exotic Block 2 and to differ moreover by the absence of the genus *Cladiscites*, which is so abundant in the Tibetan facies.

"*Dachsteinkalk*" (?)—Great masses of unfossiliferous, grey, dolomitic limestones, occurring among the exotic blocks, were oorrelated with the dachsteinkalk of the Himalayan series. It is necessary to state that there is no complete lithological identity between the two, the Tibetan grey limestones being massive throughout, while the Himalayan dachsteinkalk is well bedded.

Lias.—It has been shown above, that the lias must be looked for in the Central Himalayas in a series of conformable, grey limestones, ranging from upper triassic into middle jurassic. It is possible that limestones, including a species resembling *Spiriferina obtusa*, Oppel., which I found in Spiti in a section near Gieumal, represent the lias, but so far no unmistakable liassic fossils have been recorded. The red cephalopod limestones traced in Johar thus differ widely from the equivalent Himalayan beds, both in facies and by the fauna they include.

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[1] General Report, 1899-1900, p. 218.

[2] „ „ 1900-1901, p. 28.

We therefore learn from this comparison of the Tibetan with the Himalayan series that, though in two cases (lower trias and lower muschelkalk) a striking faunistical similarity exists, the two series differ entirely in lithological description, three of the horizons (permo-carboniferous (?), Tropites limestone and lias) being distinguished faunistically as well. The only horizon which affords points of similarity is the dachsteinkalk.

Comparison with European Alps.—To compare the Tibetan series with occurrences of similar lithological features outside Tibet, we must turn to the European Alps, where we find rocks of striking resemblance in the "*Hallstatt* limestones" and the red liassic limestones. The lithological resemblance is indeed so great that we are justified in supposing that the same physical conditions prevailed in the two areas. These conditions set in in Tibet at an earlier date (permo-carboniferous) than in the Alps (upper muschelkalk). They coincided in both areas during upper carnic and lower liassic times, but it appears that during noric times red limestones were deposited in the Alps but not in Tibet.

"*Hallstatt*" *facies.*—The Alpine *Hallstatt* facies is confined to more or less limited areas, being chiefly met with near Hallstatt, Hallein and Berchtesgaden in the Austrian and Bavarian Alps. According to Schlosser[1] it includes all the triassic beds from the "Werfen shales" (lower trias) upwards. The lowest division, the "Haselgebirge" (uppermost lower trias and lower muschelkalk), which is characterised by the occurrence of salt, has apparently no lithological equivalent in the Tibetan series and is therefore of no interest here.

All the rest of the Hallstatt facies, however, with its three main divisions: (1) "*Schreyeralm*" or "*Lärcheck*" limestone and (upper muschelkalk, horizon of *Ceratites trinodosus*), (2) carnic and (3) noric Hallstatt beds, contain red fossiliferous limestones.

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[1] Dr. Max. Schlosser, "Das Triasgebiet von Hallein" Zeitschrift d. Deutsch. Geol. Gesellsch, Vol. L, part 2, 1898.

It is sufficient for the present purpose to consider the Alpine occurrences alone. Those of Bosnia and Dalmatia can be left out of consideration.

Whitish and grey limestones occur along with the red, and the red noric Hallstatt limestones pass in places into the dachsteinkalk. While the red yield great numbers of fossils, chiefly cephalopoda, the grey limestones are poor in organic remains

There also occur breccias, made up of red, earthy and grey limestones. All the lithological varieties of the facies pass rapidly into each other, even within one and the same layer.

Red Alpine Lias—The red liassic limestones of the Alps resemble in many ways those of the Hallstatt trias with which they are also closely connected geographically. Changes of facies are common, although on the whole red limestones prevail. In the Hagengebirge, south of Salzburg in Austria, I myself [1] observed coarse breccias which answer in description those recorded from the Hallstatt beds.

Red Alpine limestones, no deep sea deposits.—The red Alpine limestones have been looked upon by some authors as deep sea deposits, a theory which owing to its bearing on the origin of the Tibetan series will have to be shortly discussed here.

As to the Hallstatt limestones, an observation, made by Prof Koken, who described their Gastropod fauna,[2] is of great importance. Koken noticed that large specimens and species almost invariably show traces of old fractures, which had healed during the lifetime of the animals and which had locally interrupted the sculpture, without in any way hindering the normal growth. From this Koken concludes that the animals lived in comparatively shallow, very rough water, perhaps in the vicinity of cliffs, which were washed by a strong surf. "Any deep sea character is hereby excluded." This conclusion is in accordance with the occurrence of breccias as recorded by Schlosser.

I arrived at similar conclusions with respect to the red liassic limestones of the Hagengebirge

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[1] Jahrbach Geol. Reichsanstalt Vienna, Vol. 47, part 2, 1897.

[2] Abhandlungen Geol Reichsanstalt Vienna, Vol. XVII, part 4, 1897, p. 3

A careful examination convinced me that these were laid down on the slopes of large reefs of dachsteinkalk, which they eventually overlapped, owing to a rise in the coast line. This, in connection with the occurrence of breccias, proves them to have been formed in comparatively shallow water.

We therefore come to the conclusion that the red Alpine limestones are not deposits of a deep sea, but of comparatively shallow water in the vicinity of grey limestone reefs, and we may conclude that the origin of the red Tibetan limestones was a similar one. On the other hand stress must be laid on the absence of sandy and shaly materials, which clearly points to an open sea, and this is no doubt, as Mr. Griesbach suggests,[1] owing to the Tibetan rocks having been deposited at a greater distance from the old Indian continent, than the Himalayan series.

From the above it appears improbable that red limestones should be of wide and equal distribution within the Tibetan series. More likely they represent local formations, while grey limestones form the predominant rock, and we may suppose that they pass into the latter in the same way that the noric Hallstatt limestones pass into dachsteinkalk.

This conclusion would be well in accordance with the observation, that within the volcanics of Johar grey limestones, mainly in huge masses, form the most prominent foreign element, whereas the red blocks—at least as far as size is concerned—play a comparatively unimportant rôle.

If the above be correct, it would of course follow that the grey dolomitic limestones represent not only dachsteinkalk but have a considerably wider range. The term "dachsteinkalk" applied to them must accordingly be understood to be of a provisional character.

In the foregoing remarks the exotic blocks, representing Spiti shales, Gieumal sandstone and upper flysch were left out of consideration. There is no reason why we should not assume them to have come from the same regions as the limestone blocks and we may conclude that the jurassic and cretaceous divisions following above the Tibetan series are of a character lithologically identical to those seen along the Indo-Tibetan frontier.

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[1] *Loc. cit.*, p. 25.

IV.—DETAILED DESCRIPTION OF THE AREA.

(*a*) The neighbourhood of the Balchdhura Pass.[1]

The boundary range rises up north of the Balchdhura pass to an insignificant peak, Balchdhura, 18,110,′ whence it runs north-west to a second point marked on the Trigonometrical Survey map, Balchdhura No 2, 18,500′. Between these two points the range describes a curve[2] with its convex side towards Hundés. Within this are two high peaks, the Balchdhura heights, as I call them; the eastern measuring 18,900′ the western slightly less.

Structure of Flysch.—To the west of Balchdhura No. 2 the boundary range is composed of Gieumal sandstone with remains of the upper flysch series, *viz*, the red shales and limestones (4*a*) which alone are preserved.

About half a mile west of Balchdhura No 2, the upper flysch is faulted against the Gieumal sandstone. On the slopes to the south and south-east of the Balchdhura heights a magnificent flysch section, the best I have seen, is exposed.

The beds have a constant dip of 10 to 15° to the north-east. Ascending this section we meet with a certain amount of folding in the black shales (4*b*), but higher up it is almost undisturbed as far as the topmost flysch beds, where there is a very striking feature. Tuffs, almost horizontal, first green, then red, end in a sort of narrow ledge, to which a débris slope descends from a small thickness of red, folded tuffs. This upper, folded tuff band yielding easier to weathering than the slightly inclined tuffs below, the formation of a ledge and a débris slope is easily understood, but the question, how the sudden change from unfolded to folded beds can have been brought about, is more difficult to answer. It must of course be due to faulting, but the latter is of an unusual and remarkable character.

The ledge, with its accompanying features, can be seen following the curve of the boundary range, for at least 2 miles, from Balchdhura

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[1] Pls. 1 and 3; section 1 on pl. 12.

[2] Not marked on the map.

No. 2 to the northern scarp of Kiogarh No. 1. Near the latter it is particularly well pronounced (see woodcut below).

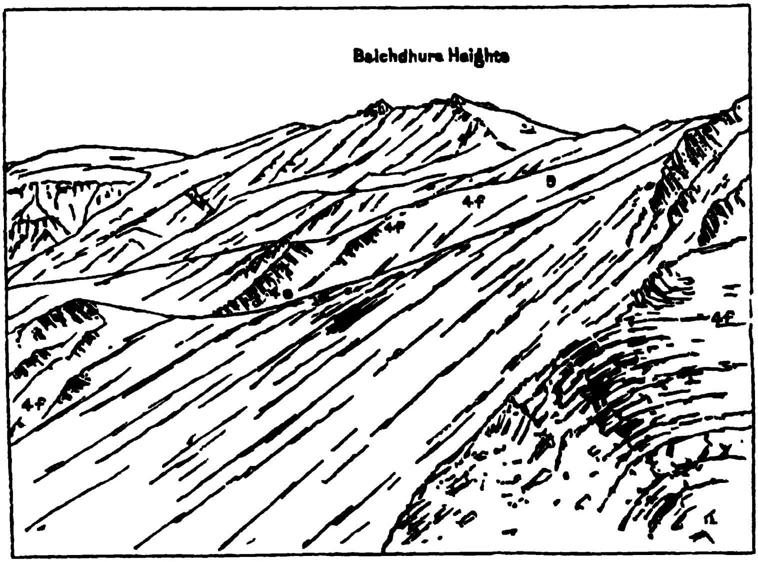

Fig. 1. Folded and undisturbed tuffs (4*f*) in boundary range, S. E. Balchdhura pass.

For the whole of this distance the fault follows the strike of the beds exactly. This peculiar fault can only be properly understood when compared with more complicated disturbances, seen in the upper flysch round the base of the Kiogarh high plateau. As the comparatively soft flysch deposits are overlaid by rigid masses, which must have been originally of a considerably greater thickness than is now observed, it is conceivable that, when the country was subject to lateral pressure, it was principally the flysch that yielded, and it also appears natural that the disturbances thus effected should be most pronounced in the neighbourhood of the boundary towards the overlying masses. The latter appear to have evaded the pressure by being pushed to some extent over the flysch. We will see below that the country south of the Kiogarh plateau is more intensely disturbed than the districts alluded to above, with the result that there the volcanics are folded together with the flysch.

Volcanics.—As soon as we have passed the folded tuff we come on the southern slope of the Balchdhura heights upon loose débris, chiefly composed of amygdaloidal andesite and red limestones. No outcrop of igneous rocks *in situ* was here observed. Involved in the débris we find large exotic blocks of various description.

Exotic blocks.—Of these I have first to mention one of green and red tuffs (4*f*), found due south below the western summit of the Balchdhura heights. It is greatly contorted and crushed but has a general steep dip towards north-east (70° to 80°). The pressure it has sustained is also indicated by almost every single bedding plane being slickensided. Red limestone blocks, mostly small in size, are also seen. Two of the largest of these have yielded fossils, *viz.*, E. B. 1 *Daonella indica*, E. B. 2 ammonites of upper carnic stage.

Exotic block 1.—Block 1 is of a longish form, divided up into several more or less disconnected parts by débris of green andesite. On the whole it can be said to dip towards north-east and strike about north-west to south-east, but neither dip nor strike are constant throughout its entire length. Faults abound and strong crushing is noticeable, the andesite being even folded into the red limestone locally.

Exotic block 2.—Block 2 with its upper carnic cephalopod fauna crops out from a débris slope to the south-south-east of the eastern summit. No bedding can be seen. The limestone is in part altered and only after some search did I find fossils in it. Near it is another rather large limestone block of pinnacle shape, made up of vertical beds, but this did not yield any fossils.

As regards the Balchdhura heights proper, they are of a peculiar description, being composed chiefly of greenish sandstones and shales, with a few isolated, densely red limestone blocks.

Gieumal sandstone blocks.—Besides these foreign elements, of which the two first I believe represent Gieumal sandstone and Spiti shales, igneous rocks play an unimportant part. We shall see later on that in the Kiogarh plateau also foreign elements predominate in places to such an extent as to exclude almost entirely the igneous rocks.

Seen from afar the Gieumal sandstones look as if they were bedded, and this no doubt was the case originally. But on closer examination this bedding is no longer recognized. The apparent layers of sandstone are found to be split up by innumerable small faults into angular fragments. Often the shaly matter has been the lubricant by means of which one block was pushed over another. The interstices between the blocks are as a rule filled out by breccia-like matter of shale with small pieces of sandstone. Large sandstone blocks make up the actual heights. The western summit is formed by a huge block with particularly bold outlines.

Balchdhura Pass.—Descending from the Balchdhura heights towards the pass we soon come upon lavas partly altered into serpentine. Thus a flat, conical elevation on the ridge near E. B. 2 is composed of that rock. A specimen of serpentine from the frontier range south-east of the Balchdhura pass was found by Mr. Holland to be an altered peridotite with chromite. The top of the range is thinly studded over with limestone and sandstone blocks, the latter being here again occasionally of large size (see woodcut below).

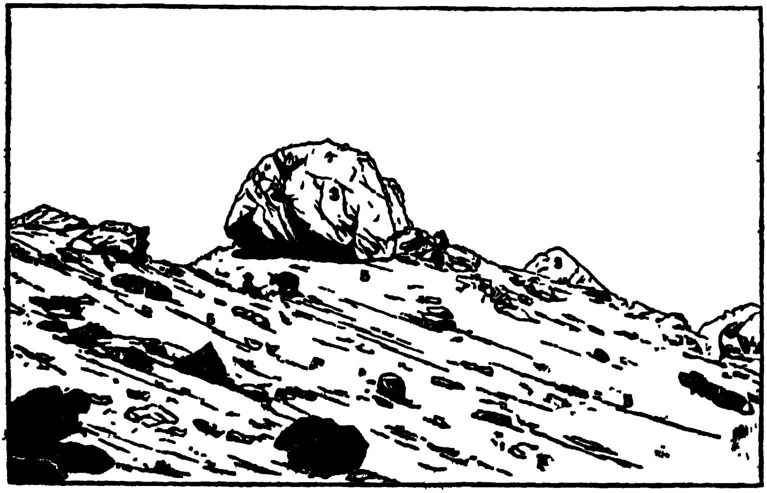

Fig. 2. Blocks of Gieumal sandstones in basic igneous rocks near Peak Balchdhura, 18,110'.

(*b*) The Kiogarh High Plateau.[1]

About one mile south-east of the Balchdhura pass there rises an extended mountain mass with a number of peaks, ranging from 18,000′ to somewhat above 19,000′.[2]

High Plateau.—The whole is a wide high plateau, intersected by two rivers (Sami and Ghátámémin rivers) and by four passes, leading from these rivers and their branches into Johar. The plateau character is most pronounced to the west of the Sami river (Kiogarh No. 1, No. 2 and No. 3). The country between the Sami and Ghátámémin valleys is modelled out into a broad ridge and a similar ridge borders the Ghátámemin valley to the east. Towards Johar the plateau ends precipitately in high, steep cliffs. There is therefore between the Balchdhura and Kiogarh-Chaldu passes no real dividing range with equally steep declivities on either side. The boundary coincides, it is true, with the watershed, but this is formed by the edge of a plateau.

The Kiogarh peaks were in 1892 recognized to be exotic masses (see introduction). Messrs. Griesbach, Diener and Middlemiss could not however attempt anything beyond a superficial examination of the area.

In the following I propose to describe first the flysch base and afterwards the masses that make up the Kiogarh plateau proper.

1.—The Flysch.

Gieumal sandstone.—The Gieumal sandstone encircles the Kiogarh plateau, without touching it, to the west, extending to the east nearly as far as Malla Kiogarh E. G.

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[1] Plates 2 and 3. Section 2 on pl 12.

[2] As the Trigonometrical survey map contains only a few names of localities which are insufficient for the purpose of a detailed description of the area, I have introduced the following new names: Kiogarh No. 1, No. 2, No. 3, No. 4 and No 5 (the latter peak is called "Kiogarh" only on the Trigonometrical Survey map), "Sami Valley" (see pl. 2), "Sami Pass," "Ghátámémin Pass," "Ghátámémin Valley," "Sami E. G.," "Balchdhura E. G.," "Kiogarh Chirchun E. G.," Talla Kiogarh E. G. I and II," "Malla Kiogarh E. G. I and II."

On the whole the beds dip towards the high plateau but are in many places folded and faulted. A beautiful reversed fault is exposed in the deep ravine of the Kiogarh river, near Talla Kiogarh I. E. G., being marked by a strip of red shales (4 *a*), hemmed in between two masses of Gieumal sandstone. A very complicated structure sets in east of Talla Kiogarh E. G. At the latter locality the sandstone disappears in a steep, almost vertical flexure with a north to south strike. Further east it again comes to the surface, greatly folded, and reaches for some distance up the various branches of the Kiogarh river. On this base of Gieumal sandstone rests the upper flysch.

Upper Flysch.—We have seen in the preceding chapter that the sequence is but little disturbed in the neighbourhood of the Balchdhura pass. The sketch on Pl. 13 shows that in ridges I, II and III no disturbances are present beyond the folding of the tūffs (sub-div. 4 *f*) and a general incline of the beds towards east and north-east. In ridges IV and V folding sets in in the sandstone (4 *e*), but the series is complete both here and in ridge VI. Ridge VII is a disturbed, incomplete flysch section. On the shales (4 *b*) the igneous rocks follow immediately. The higher flysch beds are wanting. Passing to the south-west side of the Kiogarh plateau we find much the same feature as on ridge VII. Nowhere is the upper flysch series complete. As a rule the youngest sub-division visible is formed by the shales and flaggy limestones (4 *b*), but occasionally the brown sandstones (4 *c*) are met with. Small outcrops of the tuffs (4 *f*) occur in some places but never in a normal position. As a rule they project from the black shales (4 *b*). No traces of the hard shales (4 *d*) nor of the sandstones with fucoids (4 *e*) are seen. The latter reappear however in great force on the Kiogarh-Chaldu pass.

Black shales form the chief component of the ridges descending from the Kiogarh plateau towards south-west. For this reason the structure is difficult and often impossible to unravel. Unfortunately the brown limestones intercalated with them seldom afford any help in this respect, as instead of forming clear outcrops, they weather into débris, producing light brown patches on the black shale ground.

I must therefore confine myself to mentioning a few disconnected observations that testify to the fact of intense disturbances having taken place.

From the passes between Kiogarh No. 1 and No. 2 and Kiogarh No. 2 and No. 3 branches of a small river run down towards south-west to a valley bounded on the north-west and south-east by ridges. The ridge north-west of this valley is composed, as far as the upper flysch is concerned, entirely of the red shales (4*a*) and the black shales (4*b*), the latter rich in ferruginous concretions On these shales follow immediately the igneous rocks, the rest of the upper flysch series being entirely absent

On the ridge south-east of the same valley the Gieumal sandstone is overlaid by the red and green shales (4*a*) and the black shales (4*b*). Light brown patches, produced by the weathering of the flaggy limestones, appear in several places and seem to indicate that the shales are folded. Higher up the tuffs (4*f*) appear. These are overlaid by black shales (4*b*) and these again by tuffs The latter eventually disappear beneath igneous rocks.

Between these two ridges, at the base of Kiogarh No 2, one exposure is as follows: flaggy limestones and shales (4*b*) are laid into narrow zigzag folds. Above this follows an outcrop of tuffs (4*f*) covered higher up by débris from Kiogarh No. 2.

The upper part of the flysch ridge ascending to Kiogarh No. 3 from Malla Kiogarh I E. G. is very similar to the foregoing. It is composed almost entirely of the black shales (4*b*), but here remains of the sandstones (4*c*) crop out from among the shales. The latter reach up to the débris that surrounds the base of the peak.

In the nullah ascending to the Sami pass black shales with brown flaggy limestones (4*b*) and tuffs (4*f*) are seen folded into each other. The brown sandstones (4*c*) occur here too, but there is no trace of the sandstones (4*e*). Outcrops of tuffs are again met with higher up on either side of the nullah about half a mile south of the pass. The beds are horizontal and are covered below Sami E. G. by volcanics with completely altered limestone blocks.

Further south-east towards the Kiogarh-Chaldu pass the same features prevail as in the above described ridges. But near the pass the sandstones with fucoids (4*f*) come in and form the ridge over which the pass leads into Hundés.

2.—*The volcanics and exotic blocks.*

Volcanics.—In the Kiogarh high plateau the volcanics attain their highest development. The thickness of these rocks is more considerable than either north or south of the high plateau and the number and rise of the exotic blocks exceeds anything seen elsewhere. On the whole we can distinguish a lower and an upper division. The lower one is composed of lavas, including small and large limestone and sandstone blocks, while the upper division represents a gigantic accumulation of igneous and non-igneous rocks in which grey limestones prevail, mixed with dark lavas and smaller blocks of red limestone.

Two divisions.

These two divisions are well seen in the south-west scarp of the Kiogarh high plateau, whereas in the north-west and north-east slope of Kiogarh No. 1 they are but indistinctly marked.

At the south-west slope of Kiogarh No. 1 and to the north of the Kiogarh-Chaldu pass outcrops of solid igneous rocks are seen which are practically free from foreign elements. Everywhere else exotic blocks abound, being of all possible sizes and various descriptions.

Exotic Blocks.—Red and grey limestones are most common. They are greatly altered, traversed by intrusive veins and often perfectly saturated with igneous matter, which has entered all the minor fissures. In addition to this they have undergone great crushing. This not only appears from the abundance of faults, but also from the folded intrusive veins. Red and grey limestones are completely mixed up with each other. In the ridge ascending from south west towards Kiogarh No. 1, I met with a block of thin-bedded, red limestone, shut in between two large masses of grey limestone.

Scarcity of fossils.—The limestones are mostly devoid of any fossil remains and I have only been able to trace one fossiliferous horizon. A loose block found near Malla Sangcha E. G., yielded a number of *brachiopoda* identical

Permo carboniferous.

with types described from the peak Chirchun No. 1. In spite of many days' search all over the Johar side of the Kiogarh plateau, I did not find a single fossiliferous block *in situ.*

Greenish grey sandstone blocks are also often seen, but nowhere do they alone compose large tracts, as in the Balchdhura heights.

A rare type of block is represented by thin-bedded, brown limestones (4*b*) of the upper flysch. These crop out from volcanic débris at the foot of the northern scarp of Kiogarh No. 1. The limestones are greatly contorted but show a general dip towards east (E. B. 3 on map, section 3 on pl. 12).

In describing the actual high plateau we may start from Kiogarh No. 5 and thence proceed towards the north-west. I must remark that, as the watershed forms the boundary of Hundés, which country I was not allowed to enter, my description must of necessity be incomplete.

Kiogarh No. 5.—Approaching Kiogarh No. 5 from the Kiogarh-Chaldu pass we soon leave the sandstones with fucoids (4*e*) for the basic igneous rocks, composing the boundary range up to the base of Kiogarh No. 5. They are for the greater part weathered into débris, but in one locality, on the western slope of the boundary range, not far from E. B. 8, an outcrop of lavas with sphæroidal structure is seen. With them is associated the pitchstone breccia described above.

Exotic blocks are seen in many places. The largest (E. B. 8) is represented in the photograph on pl. 7, which distinctly shows the striking contrast between the dark, basic, igneous rocks and the light grey limestones.

Reaching the base of the actual summit of Kiogarh No. 5 we arrive at a larger dolomitic limestone mass rising in steep cliffs to a height of approximately 200 feet. It seems as if it were one huge block, but very likely this is not the case, as igneous rocks crop out in places of the limestone (see drawing pl. 10). I have little doubt that peak Kiogarh No. 5 is like Kiogarh No. 3 (see next page) actually made up of an accumulation of huge limestone blocks mixed with some igneous material, but to ascertain this, the Tibetan side of the mountain should also be examined.

Ghâtâmémin Pass.—To the north-west Kiogarh No. 5 descends to the Ghâtâmémin pass, which is within the volcanics. From this pass the narrow Ghâtâmémin valley descends (N 20′E) into Hundés. This valley would probably afford a very good section through the masses composing Kiogarh No. 4 and No. 6. I could see from the pass that in the steep eastern scarp of these peaks igneous rocks are exposed, which include huge grey limestone blocks.

Kiogarh No. 4.—Kiogarh No. 4 is on its western and southern slopes almost completely covered over with débris, in which limestones predominate. Patches of dark igneous rocks occur within the limestone débris, as for instance on the ridge descending towards Sami pass.

Kiogarh No. 3.—Kiogarh No. 3 is steeply inclined towards south-west, but on the other side gradually descends into the Sami valley. In the woodcut below it may be seen that the peak is not a single block, but consists of several huge blocks, piled upon each other, with volcanics between.

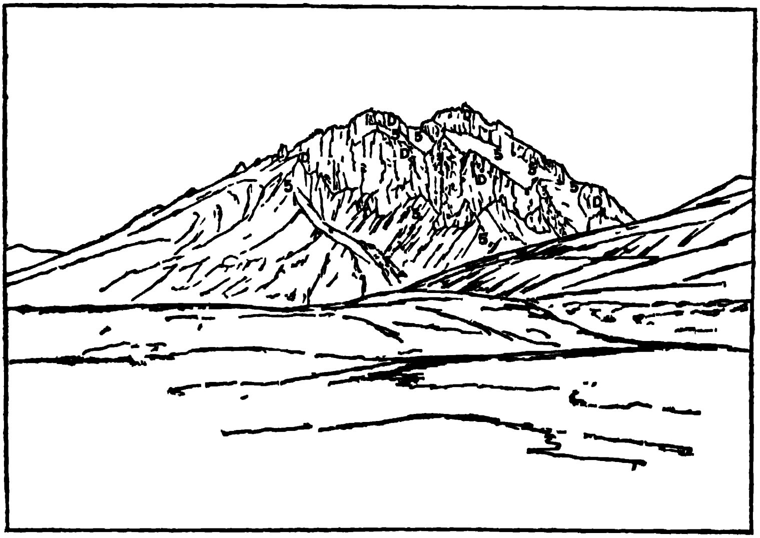

Fig 3. Kiogarh No. 3 from S.E (after a photograph).

A longish patch of igneous rocks (diabase according to Mr. Holland's determination of a hand specimen) is seen near the top of Kiogarh No. 3 on pl. 3.

Kiogarh No. 2.—Kiogarh No. 2, the lowest of the Kiogarh peaks, is in outline similar to Kiogarh No. 3. This again is more likely an accumulation of limestone blocks than a single block, although I am bound to say that I have not noticed any volcanic material within the limestones.

Kiogarh No. 1.—A view from the pass between Kiogarh No. 1 and No. 2 towards the interior of the high plateau is seen on pl. 6. The limestones have all been marked in the photograph as dachsteinkalk although subordinate red limestones are also seen. The plateau is made up of igneous rocks and limestones, which apparently compose the distant peak Ghátámémin, seen to the right on the photograph. I noticed thereabouts large masses of densely red limestones, which in tint recall the liassic blocks. The igneous rocks with the limestones included reach towards the west almost up to the summit of Kiogarh No. 1 and there cover a number of huge, grey limestone blocks which on the south-west, north and north-west scarps of Kiogarh No. 1 are exposed in perpendicular walls.[1] In the north-west slope of Kiogarh No. 1 one meets with large blocks everywhere, becoming more and more considerable in size towards the top of the peak.[2]

The photograph on pl. 5 taken from a high ridge in the north-east scarp of Kiogarh No. 1 may serve to give an idea of the coarse, tumultuous accumulation of rocks composing this peak.

Exotic block in Flysch.—Before leaving the Kiogarh peaks, mention must be made of a few exotic blocks that occur within the upper flysch near Malla Kiogarh I. E.G. (E. Bs. 4, 5, 6, 7). Blocks 4, 6, 7 are of liassic, block 5 probably of triassic age. All these occurrences are associated with igneous rocks and surrounded by the black shales (4*b*). Block 4 is made up of almost horizontal strata of concretionary limestones, the lower beds being grey, the upper red I found no fossils in these, but the lithological character of the rock makes its liassic age pretty certain.

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[1] The outlines of these blocks had to be considerably simplified on the map.

[2] Limestones and igneous rocks have been distinguished in the drawing on pl. 2 as far as possible by lettering. But it would be impossible to show the confusion prevailing more than approximately. The limestones, though not exclusively grey, have all been marked as dachsteinkalk.

Block 5 is a massive, much altered, red limestone, very poor in fossils. It has yielded one ammonite strongly resembling *Sageceras* and appears thus to be of middle or upper triassic age.

Block 6 yielded some specimens of *Arietites*. *Belemnites* and ill-preserved *bivalves* are common in certain earthy layers. The beds have a low dip towards north. I united this block on the map with a small outcrop of presumably liassic limestone to the south-west of it, which is completely unfossiliferous and shows vertical beds.

Block 7 yielded an ill-preserved specimen of *Phylloceras*. Seeing that the dip is the same as in the neighbouring block 6, the two may be connected subterraneously.

It is clear that the occurrence of these igneous rocks and exotic block in the midst of the upper flysch must be due to disturbances. Similar instances will be described below from the area south of the Kiogarh plateau (see also " Results ").

(*c*) **The area south of the Kiogarh Plateau** (Plates 4, 8, 9, and sections 3 and 4 on plate 13).

1.—*Structural features.*

South of the Kiogarh plateau the structure assumes a more complicated character.

Triasso-jurassic anticline.—There is to the west the triasso-jurassic anticline, which, appearing underneath the Spiti shales in the ravine of the Kiogarh river somewhat below Talla Kiogarh I. E G., gradually ascends towards the high peak Lahur (app. 18,000 feet).

East of the anticline a thrust-fault is seen, and what lies east of the latter consists of flysch and the eocene igneous rocks, no older beds than Gieumal sandstone being exposed. The fault appears to have been originally a narrow syncline which was subsequently converted into a thrust-fault with the result that parts of the lower limb of the original syncline were cut out.

The anticline is of a dome shaped character. At the base it is denuded down to the middle jurassic limestones, Spiti shales being preserved in one small patch only. The eastern limb, however, includes Spiti shales, Gieumal sandstone and part of the upper flysch. This limb is generally of a simple structure, the dip being low, but in the neighbourhood of the fault, the structure becomes complicated. I have already described the flexure which suddenly sets in at Talla Kiogarh II. E.G., and further east the beds, chiefly Gieumal sandstones with remains of upper flysch, are laid into narrow zigzag folds until the fault is reached.

We have now to consider the structure of the area to the east of the fault.

Near Kiogarh Chirchun E G a magnificent section is exposed, plainly showing an overfold made up of Gieumal sandstone, upper flysch and the eocene volcanics (see pl. 4).

Over-fold in Flysch.—The longer limb of the overfold is little disturbed and represents from the Gieumal sandstone up to the sandstones (4*e*), a normal sequence of beds. Above the last mentioned sandstones the tuffs (4*p*) should be found, but they must be wanting as they were nowhere observed, a fact which, as will be shown below, must be explained by denudation having preceded the volcanic eruptions. In the case of the overfold a small reversed fault is seen which traverses the brown sandstones (4*c*), and the hard shales (4*d*).

In the lower limb, which is partly encumbered by débris, the only flysch divisions visible are the red shales (4*a*) and the sandstones (4*e*). This overfold borders to the west on the great thrust fault. Here an anticline of Gieumal sandstone is seen, which is covered by remains of the red shales (4*a*). Between this and the sandstones (4*e*) the basic igneous rocks have been squeezed out and reduced to a lens-shaped complex, connected with a block of completely altered limestone (E. B. 10), and further north-east in the strike of the fault-plane, there is another very large limestone block of permo-carboniferous age (E. B. 9), which also originally belonged to the lower limb of the overfold, but has been isolated by denudation.

The fault-plane also cuts through the lower part of a ridge situated between two branches of the Kiogarh river (ridge II in section 3, pl. 12). The features are much the same as further south, but there are no igneous rocks seen along the fault. The black shales (4*b*), here partly preserved, are followed immediately by the sandstones (4*c*).

Further north the fault could not be traced, but the exotic blocks seen near Malla Kiogarh I E.G , may be supposed to lie in the strike of the thrust-plane, which may account for the abnormal position of these blocks also.

Towards the south the fault crosses the range and then runs along the western foot of the ridge which bears E. B. 20. The greater part of the flysch is here cut out, but owing to the inaccessibility [1] of this area, the structure could not be cleared up satisfactorily.

Sections through ridges near Kiogarh Chirchun E. G.—To the east of the overfold we come upon another complicated section. The beds descend in a low dip to the east and cross the path leading to the Kiogarh-Chirchun pass. At this place one of the branches of the Kiogarh river cuts a ravine through them, thus affording a very good exposure. (See ridge I in section 3 and section 4, pl. 13). At the base of the ridge there are the sandstones (4*e*) and faulted on top of them a small thickness of shales and sandstones representing part of another mass of division 4*e*. The beds therefore are doubled owing to a reversed fault (*a*—*a*), which is very sharply marked, as the upper sandstone beds can be seen to be cut off abruptly by the fault.

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[1] To work out this corner I had to camp at 18,000 ft. Unfortunately I was driven down by heavy snow after a short stay.

Above the upper sandstone remains of igneous rocks are seen, but the tuffs (4*f*) are not present here either. The volcanics are overlaid by black shales with thin-bedded brown limestones (4*b*), the result of a second reversed fault (*b*—*b*). Recurring patches of débris from the brown weathering limestones suggest great complications in the structure of sub-division 4*b*, which have been indicated on the section by a number of diagrammatic folds.

The two faults are also seen in ridge II to the north of Kiogarh Chirchun E.G.[1] We have seen above that in this ridge the sandstones (4*e*) follow above the great thrust-fault, which traverses the lower part of it. At first these sandstones lie almost flat, but rather more than half way up an eastern dip sets in abruptly, the result of fault *a*—*a*. In this ridge the shales, which are noticed in ridge I, are completely cut out. Above the sandstone remains of igneous rocks are found here too, but they disappear at the ridge and are cut out further north. The igneous rocks are here as in ridge I overlaid by black shales (fault *b*—*b*). Further north the sandstones (4*e*) reach as far as Malla Kiogarh I, where they disappear under the shales 4*b* (pl. 3). South of ridge I, the structure is less clear, but it can be seen that the volcanics swell out considerably in this direction. Here again compact lavas are seen which show the same sphæroidal structure as those near Kiogarh-Chaldu pass. They contain small blocks of a densely red limestone and are associated with breccias made up of andesite and red limestone.

These igneous rocks are connected with those which further west cover the root of the overfold, and this indicates that the sandstones overlying fault *a*—*a* in ridge I represent a wedge that thins out towards west. East and south of these igneous rocks shales (4*b*) are met with, which are no doubt faulted against them (fault *b*—*b* in ridge I).

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[1] See also view on pl. 3 to the right.

2.—*The Exotic blocks.*

South of the Kiogarh high plateau igneous rocks occur in three patches. The largest of these is very complicated in outline, owing to the disturbances it has undergone. It is remarkable for its very interesting blocks. Of these E Bs. 9, 13, 15 to 18 and 20 yielded fossils, pointing to permo-carboniferous (9, 13, 15, 18), lower liassic (16,17) and lower triassic age (20). Other horizons represented are: Gieumal sandstone, dachsteinkalk and upper flysch, sub-division 4*b* (14 on map). We will first consider the—

Permo-carboniferous blocks.—E. B. 9 is the largest of that age found in Malla Johar. It is comparatively little altered, no doubt in consequence of its size. As recorded above, rare permo-carboniferous *brachiopoda* are found in it. A few fossils of this age were also found in blocks 13, 15 and 18. A permo-carboniferous age can safely be inferred with respect to blocks 11 and 12, as large crinoid stems abound in them. Block 10 and several others (left out on map) are of doubtful age. What has been mapped as E. B. 18, is a large number of blocks of red and white limestones (pl. 9). They yielded a few permo-carboniferous species.

Lower Liassic blocks.—In the vicinity of E. B. 18 intensely red, conspicuous patches of débris are seen. In these *ammonites* of lower liassic age were found. In one place the limestone is *in situ* (partly to be seen on pl. 9). There it is noticed that the rock is bedded, concretionary, chiefly of red colour but with a few grey layers, thicker than the red beds. It is impossible to say how many liassic blocks were originally present, as they have all been more or less decomposed into large patches of débris. We can distinguish two main occurrences, one (E. B. 17) situated near E B. 18 and the other, E. B. 16 somewhat higher up near the crest of a ridge running from south to north.

Lower triassic blocks (Fig 4 below).—On the frontier ridge south of the liassic crags an occurrence of red limestones with *ammonites* of lower triassic age was discovered. This again is not a single block but an accumulation of large sized blocks.

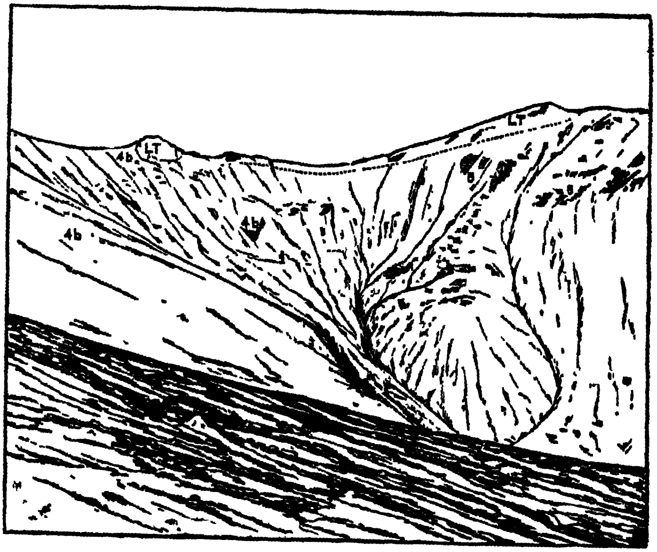

Fig. 4. Exotic block 20 from North.

The collections referred to were made from the small peak seen to the left on the above woodcut.

This small peak consists of rather thin beds, dipping approximately 80° south-east and striking south-west to north-east. The limestone is chiefly red with subordinate grey layers. It rests on green andesites and volcanic breccias.

To the east the block borders on the black shales (4*b*) which compose the boundary range to a short distance beyond the Kiogarh-Chirchun pass. Thin-bedded distorted brown limestones of the upper flysch (4*b*) crop out from the débris slope south of the E. B.; but I could not determine whether these represent another block or not. Débris of red limestone connects the small block I have just described with similar limestones capping the boundary range further west, which are also underlaid by igneous rocks. This latter part of E. B. 20 also extends for some distance south, where the boundary range turns round towards peak Kungribingri No. 2. The rock is extremely altered and calcspar veins abound in it, but there is an approximately horizontal bedding seen in places. Traces of *ammonites*, resembling *Danubites* and *Flemingites* are not uncommon, in spite of the altered state of the rock. From the highest point of block 20 (app. 18,500′) it may be seen that igneous rocks reach down towards south-east into a valley running in the direction of Chirchun E. G. In this valley exotic blocks also occur.[1]

Unfossiliferous blocks.—We now proceed to consider the unfossiliferous blocks.

Sandstone blocks, apparently representing Gieumal sandstone, may be seen almost everywhere, especially near the liassic block No. 16, where they are perfectly denuded out of the igneous rocks and near E. B. 12 (see pl. 4 and map).

Grey limestones (dachsteinkalk) occur in one or two places in the vicinity of the liassic blocks. The limestone is decomposed into small débris heaps.

E. B. 14 is an occurrence of black shales extremely crushed and weathering rusty brown, which looks exactly like certain palæozoic shales. Ferruginous concretions being common and brown weathering flaggy limestones with plant remains interbedded, there can be no doubt that the occurrence represents sub-division 4*b* of the upper flysch.

Two small patches of igneous rocks are seen at a short distance to the north and north-east of the Kiogarh-Chirchun pass. The larger of these includes an accumulation of large blocks, mapped as exotic block 19 (pl. 8). This is one of the most conspicuous blocks of the area, but unfortunately is devoid even of traces of fossils. The limestone is much altered, massive, of a red and white streaky colour, and in my opinion is of the permo-carboniferous block type. On one side it is bordered by black shales (4*b*), on the other side by igneous rocks (5).

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[1] One of these exotic blocks is represented on both Mr Griesbach's and Dr. Diener's maps. In addition to these I have marked two others which I noticed from a distance.

V.—RESULTS.

In the preceding chapters all but occasional references to the question of the origin of the exotic blocks has been purposely omitted. The subject is one whose complexity deserves a special treatment, which could not be undertaken before the area had been fully described.

Before proceeding to express my own view, I must deal with the theories applied to the European "Klippen" which are discussed by Diener in connection with the exotic blocks of Tibet and Johar. As, however, none of these holds good in the present case, I do not propose to enter at any length into this subject, and I may be allowed to refer the reader for more detailed information on these theories to Prof. Diener's paper.

Exotic blocks not due to structural causes—It will be found that, with the exception of one, all the theories in question, as well as that advanced by Mr. Griesbach, consider the "Klippen" to be the result of one or the other form of structural causes, be it faulting (Griesbach), crushing of anticlines (Neumayer and Studer-Moesch), or overthrusts (recumbent folds) (Bertrand and others).

One theory (Stache-Uhlig-Renevier) applied to Carpathian and Swiss occurrences, explains the "Klippen" as outcrops of an older series, unconformably overlaid by younger deposits. I need hardly say that in no respect can the latter theory be seriously discussed in connection with the Johar and Chirchun blocks.

Those which assume structural causes would imply that the exotic blocks were brought into existence by the disturbances which lead to the upheaval of the Himalayas. This, however, is not the case. We have seen that the volcanics, which include the blocks, were folded together with the flysch. From this we can only conclude that the volcanics and consequently also the exotic blocks were pre-existent to those disturbances, and any causal connection between the latter and the blocks is therefore impossible.

Nor is it at all conceivable that folding or faulting should have brought about those features, which were described in the above chapters. None of the theories alluded to would explain the presence of the volcanics and their intimate connection with the exotic blocks.

A simple and as I believe satisfactory solution of the problem is, however, obtained if we attribute the exotic blocks to volcanic outbursts.

We have seen above that the exotic blocks are involved in volcanic rocks and it cannot for a moment be doubtful that both the volcanic and non-volcanic rocks came into existence simultaneously. No more likely conclusion can therefore be drawn, than that the exotic blocks are caused by volcanic eruptions. They must be derived from rocks which were shattered into pieces by steam blasts and hurled up and ejected or floated upwards by erupting lavas through volcanic vents.

The exotic blocks thus must be understood to be fragments, torn from rocks *in situ*, through which the eruptive forces opened their way. In many cases the limestones had been intruded by igneous rocks, previous to their being torn off and ejected, and some of them underwent great pressure subsequently with the result that the veins were plicated.

Let us for a moment put aside those huge masses of grey limestone and Gieumal sandstone, found within the Kiogarh high plateau and the Balchdhura heights respectively and only consider the accumulation of lavas and smaller non-volcanic blocks, which is general in Johar. Numerous instances of similar occurrences from other parts of the world can be quoted, which are universally explained by volcanic outbursts. The fragments of slate, which largely make up the volcanic cones of the Eifel, the fragments of cretaceous limestones found on the slopes of Mount Vesuvius, the abundant non-volcanic materials imbedded in the carboniferous volcanic rocks of the Firth of Forth,[1] sandstones with rhaetic fossils, limestones with liassic fossils and fragments of cretaceous (?) chert, recently discovered in the vent of a tertiary volcano on the Isle of Arran;[1] limestones with fossils included in tuffs of the volcano of Santorin;[2] crag-shaped, marmorized limestones and alabaster found in the crater of the volcano Palandokan in Armenia;[3] further, pieces of older rocks, "crowded with crinoids" occurring in the eocene traps of the Indus Valley,[4] all these occurrences fall more or less into line with the exotic blocks of Johar and Tibet. These instances could be greatly augmented, but those mentioned will suffice.

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[1] Geikie, Transactions Roy. Soc, Edinburgh, Vol. XXIX, 1880.

Counter arguments.—The theory here advanced was shortly discussed and rejected by Diener in his " Ergebnisse," p 606. According to him it would be wrong to imagine that the exotic blocks had been torn off from the depth and brought up by igneous rocks, like the ejected fragments of cretaceous limestone in the lavas of Mount Vesuvius. His arguments are that the unaltered state of the limestones of Peak Chirchun No. 1 and the good preservation of the fossils even on the contact with the igneous rocks as well as the absence of contact minerals exclude this theory.

These arguments might, however, be met by counter arguments. First of all we know now that fossiliferous blocks are greatly in the minority, the bulk being entirely altered. Diener himself noticed this near Talla Sangcha (l. c. p. 600), remarking that the limestones are " for the greater part crystalline, marmorized and highly altered in the contact."

On the other hand the little altered state of and the occurrence of well preserved fossils in a few of these innumerable blocks does not tell as much against my theory as Diener was inclined to believe.

The limestones ejected by Mount Vesuvius have yielded several hundred species of shells, which cannot have been of very bad preservation, since they were specifically determinable.[5]

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[1] Summary of progress of the Geological Survey of the United Kingdom for 1899, p. 133.

[2] Fritsch Zeitsch. d. Deutsch Geol. Gesellsch, XXIII, 1871, p. 208.

[3] Abich, Geologie des Armenischen Hochlandes, Western half, 1882, p. 76.

[4] Lydekker. Mem. XXII, p. 113.

[5] Judd, Volcanoes, p. 45.

In his description of the carboniferous volcanic rocks of the Firth of Forth basin Sir A. Geikie[1] remarks: "In a great many cases the fragments of shale, sandstone and other sedimentary strata imbedded in the ejected débris are so unchanged that they cannot on a fresh fracture be distinguished from the parent beds at a short distance from the vent. The *Spirifers*, *Lingulae*, *Crinoids*, *Cyprid*-cases, *Ganoid* scales and other fossils are often as fresh and perfect in the fragments of rock imbedded in tuff as they are in the rock *in situ*" Indeed in most of the occurrences compared above with the volcanics of Johar, determinable fossils have been found.

The absence of contact minerals is a still less conclusive objection. Diener himself describes Peak Chirchun No. 1 as being traversed by a dyke and yet no contact minerals were found. Nor have I discovered any near the intrusive veins so often met with in exotic limestone blocks. If then they were not produced by these intrusions, there is no necessity why they should be present at all.

But there is another more powerful objection that might be raised to the theory advanced above.

We have so far not taken into account those huge, grey limestone masses, found within the Kiogarh high plateau and the large masses of Gieumal sandstone occurring in the Balchdhura heights The size of these blocks is so stupendous, that the impossibility of their being ejected through volcanic vents might be urged. I am unfortunately not in possession of exact data as to the volume of the largest blocks, yet there can be little doubt that some of them are many thousand cubic yards in bulk. To bring up such enormous masses, eruptive forces are required infinitely more violent than those to which the non-volcanic fragmental materials of Mount Vesuvius or the Eifel are due, and yet this is, in my opinion, the only possible explanation.[2] We must indeed assume that the geological phenomenon is the same in Johar and Tibet as in the instances quoted, but that the scale on which it worked was a very much larger one. This latter assumption is fully justified by the fact that the volume of the fragmental materials as a whole and the size of many of the detached blocks exceeds anything known from the instances alluded to above.

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[1] Transactions Roy. Soc, Edinburgh, Vol. XXIX, 1880, p. 459.

[2] There can be no question of the large blocks being in origin essentially different from the smaller ones. The limestone fragments met with are of all sizes from small pieces up to huge blocks, the two extremes being linked by every possible intermediate size. On the whole, the higher we ascend in the volcanics, the larger the blocks, but also the largest ones are surrounded and partly covered by igneous rocks, in which small sized limestone fragments occur.

I am not aware of any occurrence in other parts of the globe which could be directly compared to the one here in question, but the extreme violence sometimes displayed during volcanic outbursts may be illustrated by a few instances.

As to recent volcanoes the outbursts of G. Pepandajan in Java in 1772 may be quoted. According to J. Junghuhn[1] an area of more than 20 square miles was covered to an average thickness of 50 feet by lava blocks and finer detritus, erupted during a single outburst. Measured from the middle of the crater to the most distant boundaries of the ejected material, this area had a length of more than eight miles. The volume of the erupted masses is said to have been 29,343 million cubic feet.

The volcano of Cotopaxi has been known to throw out, to the distance of eight or nine miles, a mass of rock about one hundred cubic yards in volume.[2]

Attention may further be drawn to a remarkable occurrence in the tertiary basalts of the Isle of Mull, described by Sir Archibald Geikie.[3] Near the summit of Sgurr Dearg, bedded basalts enclose "a lenticular band of exceedingly coarse breccia, consisting mainly of angular pieces of quartzite with fragments of amygdaloidal basalt. In the midst of the breccia lies a huge mass or cake of erupted mica schist, at least 100 yards long by 30 yards wide, as measured across the strike up the slope of the hill……A little higher up, other smaller, but still large blocks of similar schist are involved in the basalt. As the huge cake of mica schist plunges into the hill, its whole dimensions cannot be seen, but there are visible at least 15,000 cubic yards, and which must weigh more than 30,000 tons."

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[1] "Java," 1854, p. 103.

[2] Lyell, Principles of Geol., Ed. 10, vol. II, 1863, p. 223.

[3] "On the history of volcanic action during the tertiary period in the British Isles." Transactions Roy. Soc., Edinburgh, vol. XXV, 1890, p. 82.

Sir Archibald Geikie thinks there can be no doubt that these enormous fragments were torn off from the underlying crystalline schists and were floated upwards in an ascending flow of molten basalt.

Site of volcanoes uncertain.—But now the question arises: Where are these volcanoes situated? As they were in action during eocene times we cannot of course expect to find well preserved cones anywhere, but remnants of these must be present, and it should be possible at least approximately to fix the site of these old volcanoes.

At present, however, no direct attempt can be made in this direction, as our knowledge of the structure of the Tibetan districts to the north, north-east and east of Johar is extremely limited. We know from Strachey's researches that great masses of "greenstone" are found in Hundés, *viz.*, to the west of the Manassarawar lake and to the east of Kiunglung on the Sutlej. These rocks are according to Strachey older than the subrecent deposits of Hundés[1] and no doubt contemporaneous with the Indus valley volcanoes and with those of Johar and the Chirchun area. It appears that they represent lava flows, but no details are known.

On the other hand I could see from the boundary range that the Johar volcanics extend several miles to the north, north-east and east into Hundés, especially in the Kiogarh high plateau, the eastern limits of which are yet unknown.

The country intervening is, according to Strachey, covered with mesozoic and subrecent deposits.

In view of the huge size of some of the blocks ejected, the position of the Kiogarh high plateau in the centre of the Johar volcanics and the great thickness of the latter, it might be supposed that the sources of discharge lie within this plateau. But there are other considerations to be borne in mind. The absence of dykes in the flysch in Johar points to the volcanic vents being at a greater distance, and the same must be concluded from the unusual facies of the limestone blocks ejected.

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[1] *Loc. cit.*, p. 310.

From all we know, we cannot but infer that the Himalayan, and not the Tibetan series, is *in situ* below the Kiogarh high plateau.

Messrs. Griesbach and Diener were of different opinion, but at that time the Tibetan lias was not yet known. Dachsteinkalk and younger beds were found to be close to the Spiti shales—flysch belt of the same description as elsewhere.[1] There was therefore no question of a change of facies in these beds, and as regards the peculiar characters of the permo-carboniferous, lower muschelkalk and upper carnic horizons of the Tibetan series, even then observed, they were explained by the assumption of a change of facies taking place towards the north.[2]

By the discovery of the Tibetan lias, the aspect of the question has been considerably altered.

The occurrence of the Himalayan triasso-jurassic, grey limestone series, close to the belt of sedimentary rocks, appears now in a perfectly different light. Far from being natural, as it had seemed to be, it is a most striking feature and difficult to explain. Instead of changing their facies, we now know that at least the younger beds remain unchanged up to the margin of the belt, and this being so, it is probable that the older horizons behave in the same way.

Consequently we are not justified in assuming that the Tibetan facies should be *in situ* below the Kiogarh high plateau.

Conflicting evidence.—The evidence is therefore decidedly conflicting. On the one hand the existence of vast masses of detached blocks points to the vents occurring within or close to the Kiogarh high plateau, while on the other hand the facies of the ejected blocks almost forces us to suspect the sources of discharge to lie much farther to the north.

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[1] *Viz.*, in the anticline to the south-west of the Kiogarh plateau and in the Chanambaniali peaks to the east of Chirchun E. G. The expedition of 1892 ascertained that in these peaks a regular series from the Spiti shales down to the dachsteinkalk is exposed, which differs in no way from what is seen in the Himalayan series (Diener, "Ergebnisse," p. 585).

[2] In a syncline at the head of the Dhauli river (Mem. XXIII, p. 171, fig. 23) the series from the carboniferous quartzite up to the Spiti shales is of the Himalayan facies. "This locality is not more than 7 or 8 miles distant from Peak Chirchun No. 1."

It would appear either that the facies changes very rapidly or that the erupted masses are spread over an enormous area. As both these eventualities seem equally improbable, we find ourselves face to face with an obstacle, at present unsurmountable.

Events before and after the volcanic eruptions.—Having in the foregoing discussed the volcanic outbursts, which gave rise to the exotic blocks, we must now consider the events that happened before and after the eruptions.

In the first place the age of the uppermost flysch beds will have to be discussed, a question which has so far scarcely been touched upon. To arrive at a conclusion we must start from the Indus valley tertiaries. The nummulitic beds of this area are limestones, shales, sandstones and conglomerates, with which the volcanic traps are in the main contemporaneous.[1] The nummulitics appear to extend eastwards as far as the area north of the Niti pass, for Mr. Griesbach mentions contorted nummulites from a series of altered beds, which also is connected with igneous rocks [2]

Flysch in its entirety of cretaceous age.—The features observed in Johar are however entirely different. We have seen that subaqueou tuffs appear in the topmost flysch series, but these are of small thickness and cannot be compared with the contemporaneous traps as recorded from the Indus valley. Limestones with *Nummulites* wer nowhere found. On the other hand we meet with subaerial volcanic which overlie the tuffs and are decidedly younger, including as they d fragments of the latter. At the same time these volcanics are fre from any contemporaneous sedimentary beds. Now we cannot bu assume that the lavas of Johar have been erupted during the sam period as the traps of the Indus valley, *viz.*, that they are of eocen age. The most likely conclusion therefore is that the flysch does no reach into the lower tertiaries, but is in its entirety of cretaceous ag

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[1] Lydekker. Memoirs, XXII, p. 111.

[2] Memoirs, XXIII, p. 83.

Elevation of sea floor.—As the subaqueous tuffs are abruptly overlaid by clearly subaerial volcanics, we must infer that, at least locally, an elevation of the sea floor has taken place, and this would point to the sedimentary beds having for some time been subject to subaerial denudation.

Subaerial denudation, previous to volcanic outbursts.—As regards the latter, I must confess that no conclusive evidence is available, but the absence of the tuffs (4*f*) in the sections south of the Kiogarh high plateau is no doubt an argument of some weight. Mr. Griesbach's map of the Chirchun area further shows in two places igneous rocks overlapping the flysch and the Spiti shales, a feature which would be perfectly congruous with denudation, preceding the outburst of the valcanoes.

Later disturbances.—As stated above the volcanic outbursts were followed by disturbances These are the more intense the farther south-east we go, and this fact can be accounted for by a change in the strike.[1]

To the north-west of Laptal, there is a broad, slightly disturbed belt of Spiti shales and flysch striking north-west to south-east. This belt becomes gradually much narrower and more complicated further south-east, the strike changing to north-south, and it ends within the corner described by the boundaries of Dharma, Johar and Hundés.[2] Thus the Spiti shales dwindle down to narrow strips and the triasso-jurassic anticline appears, while the structure of the flysch gets gradually complicated. At the same time there appears in Hundés the anticline of the Chanambaniali peaks, as a counterpart of the anticline of the Lahur.

Effect on volcanics.—These disturbances have affected the volcanics too, but only in the south-east corner of the belt. In the neighbourhood of the Balchdhura heights they were of too small an intensity to have any perceptible effect on the volcanics, while the thick and rigid masses of the Kiogarh high plateau appear to have resisted a pressure that caused great complications in its more easily yielding flysch base.

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[1] See also Griesbach, Memoirs, XXIII, and Diener, Ergebnisse, p. 604.

[2] See geological map in Griesbach, Memoirs, XXIII.

To the south of the Kiogarh plateau, however, where the igneous rocks may originally have been less in force, they participate in the folds and faults like the sedimentary components of the country. This is why we find exotic blocks within the flysch, those either isolated from the igneous rocks like E. B. 9, or connected with remnants of them like E. B. 19.[1] This must be borne well in mind, if we want to understand the Chirchun area, which is also situated within the narrow, complicated southern termination of the Spiti shales—flysch belt.[2]

Comparison of Chirchun area with Johar.—This area will now have to be compared with that of Johar, in order to ascertain whether the explanation given for the origin of the exotic masses is in accordance with what is recorded from the Chirchun area

The description given by Diener is in extract as follows[3]:—

The limestone blocks of the Chirchun area are of much smaller size than those of Malla Johar. They exhibit in their strike an almost semi-circular arrangement, forming at the same time three distinct rows or zones.

1. The most northern of these rows has been but superficially reconnoitred by Mr. Middlemiss. It is made up of three blocks,[4] *viz*, Chaldu No. 1 and two lower cliffs lying on the eastern scarp of that peak. The latter is an isolated mass of a white, semi-crystalline limestone with a north-east strike. Lithologically it is exactly similar to the permo-carboniferous limestone of Peak Chirchun No 1. Apparently it rests on Gieumal sandstone and on the igneous rocks,[5] associated with

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[1] Also E. Bs. 4, 5, 6 and 7 might here be mentioned. They have no doubt been involved in the flysch by similar disturbances as block 9.

[2] Griesbach, Records l. c., mentions "numerous tight folds and narrow anticlinals," the dip "changing constantly and rapidly."

[3] Memoirs, XXVIII, Part 1, pp. 6 to 12. The geological mapping of the Chirchun area was compiled from Diener's and Griesbach's maps. The whole of the flysch is marked with light green, the colour which in Johar represents upper flysch only. A compilation from both maps was unavoidable. Mr. Griesbach's map has the great advantage of showing the igneous rocks, which were left out entirely by Prof. Diener. On the other hand Diener mapped certain blocks which were not indicated by Griesbach.

[4] Mr. Griesbach's map shows one block only.

[5] Not shown on map.

the latter. The occurrence is marked on Diener's and Griesbach's maps as permo-carboniferous.[1]

2. A central row of much greater extent and containing by far the largest number of isolated blocks, stretching from Peak Kungribingri, 19,170′, towards the watershed of the Chaldu and Chirchun rivers.

This row is formed by:—

(*a*) A block south of the Kiogarh-Chirchun pass. It was not examined in detail, but appeared to consist of a bright coloured limestone.[2]

(*b*) Top of Kungribingri, 19,170′, a small block of white limestone resting on greenish Gieumal sandstone, without fossils.[3]

(*c*) A block in the immediate vicinity of Chirchun E. G., in the ravine descending from the Kiogarh-Chirchun pass towards the Chirchun river. This block is almost entirely imbedded in Spiti shales.[4]

(*d*) A block near the low pass west of Peak Chirchun No. 1. It yielded a few sections of *Bryozoa* and *corals*.[5]

(*e*) At the same locality also a few blocks with *Monophyllites* and *Xenaspis* (?) (lower muschelkalk) were observed.[6] Blocks (*d* and *e*) rest on Spiti shales.

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[1] Fossils being wanting, the age of these limestones is uncertain. I consequently marked them as blocks of uncertain age, and the same course was followed in most of the Chirchun blocks, whose age is not established.

[2] According to Diener it is entirely imbedded in Spiti shales, while Mr. Griesbach shows "rhætic" (middle jurassic) (?) limestones bordering on it. Griesbach, l. c., p. 22, remarks there are several blocks in the ravine west of Chirchun E. G. I also noticed them from E. B. 20 (see map).

[3] Copied from Diener, who ascended the Peak.

[4] According to Griesbach's map rhætic middle jurassic (?) limestones border on it from south-east. Diener marks another small block near block (c) which does not appear on Griesbach's map. The latter shows instead a patch of igneous rocks overlapping the Spiti shales and flysch. Copied from Mr. Griesbach's map.

[5] Copied from Diener. Griesbach's map shows this block further south-west than Diener's.

[6] Copied from Diener, not marked by Griesbach.

(*f*) Block composing Peak Chirchun No. 1[1] rich in permo-carboniferous fossils. According to Diener it is difficult to say whether the block actually comes into contact with the Spiti shales or with "the intrusive rocks and their tufa" only, the two being mixed up together. The intrusive character of the igneous rocks is said to be proved by the existence of a vein, running up the side of the block. The crown of the latter is composed of igneous rocks. The latter "penetrate in succession the Spiti shales and the block in question." According to Diener, no distinct stratification is seen, whereas Griesbach recognised (Records l. c., p. 23) an almost horizontal stratification.

(*g*) A block immediately to the east of Chirchun No. 1, about 130 feet high, of conical shape, resembling lithologically the dachsteinkalk.[2] This block is surrounded to the north-west and south by "intrusive rocks". The eastern slope was not visited.

(*h*) A long ridge,[3] forming a continuation of Chirchun No. 1, towards north-east and north, is capped by masses of limestone similar in appearance to the block of Chirchun No. 1. The strike gradually passes from north-east to north. These limestone masses, mapped by Diener as one lenticular block (permo-carboniferous), were not examined in detail.

This central row describes a flat semicircle with its convexity towards south-east.

3. The southern row, considerably shorter than the central one, is made up of three small blocks to the west and north of Lochambel-ki-

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[1] Copied from Mr. Griesbach's map.

[2] Copied from Prof. Diener. Griesbach shows this block one mile north-north-east of Chirchun No. 1. This block and a block two miles north of Lochambel-ki-chak E. G., also dachsteinkalk were coloured with the same tint as the grey dolomitic limestone blocks of Johar. Whether the rock is the same or not I am of course unable to decide.

[3] Copied from Griesbach.

chak E. G. and by an outcrop of dachsteinkalk in the Spiti shales two miles north of this E. G. The latter outcrop may be an inlier of the upper triassic limestone of Peak Chaldu No. 2.

One of the three small blocks is of permo-carboniferous age (not mapped) the other two[1] are lower muschelkalk with *Monophyllites*, *Xenaspis*, etc., developed in a Hallstatt facies.

Diener's description no doubt disagrees in most important respects with the theory I have advanced above. He speaks here again of intrusive rocks and recognises a semi-circular arrangement of the exotic blocks, to which he attributes great structural importance.

Great weight is attached both by Mr. Griesbach and Dr. Diener to a dyke seen in the block that makes up Chirchun No. 1, and this is taken as a proof of the intrusive character of the igneous rocks, which are asserted to traverse in succession both the Spiti shales and the block.

I have no doubt this dyke answers to the veins so often seen in the exotic blocks of Johar, and altogether the feature appears to be exactly the same as elsewhere, a limestone block with intrusive veins resting on volcanics by which its top is also covered. That the igneous rocks should pierce through the Spiti shales is not compatible with the results of my own observations, all accounts pointing to the conclusion that the sources of discharge of these rocks lie elsewhere. If there were a dyke in the Spiti shales, one should expect it to be very clearly seen as the igneous rocks are harder than the shales. Nothing of the sort has been recorded.

Diener deems the semi-circular arrangement of the exotic blocks to be of vital importance, on the grounds that the rows run diagonally to the direction of the Himalayan folds outside the Chirchun area.

The northern and southern rows are too indistinct to deserve much attention, but the "central row" can to a certain extent be recognised in Diener's and Griesbach's maps, although the two maps differ in detail. It is on these maps pretty well pronounced from Chirchun No. 1 north and north-eastwards, but to the south-west of that peak it is no longer clearly seen. Indeed it appears somewhat far fetched to say that the few scattered blocks to the south-west of Chirchun No. 1 form a continuation of the latter.

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[1] Copied from Diener, not shown by Griesbach.

The northern continuation of the ridge to which Chirchun No. 1 belongs was admittedly seen from a distance only. I also saw it from afar (pl. 11); my impression of the structure of this range differs however widely from that of Diener. At any rate it is not made up of a single, lenticular limestone mass, but represents a hilly country, which from its predominantly dark colour appears to be chiefly igneous. This is studded over, not only on the top of the range but also on its slopes with numerous light coloured limestone blocks.[1] That this range has, as a whole, a slightly semi-circular bend is in my opinion the consequence of erosion, as the same curve is followed by the Chalda river that washes its western slope.

In view of the foregoing the arrangement of the blocks in rows can hardly be said to be an established fact. The only district where such rows might be suspected from the maps in hand has never even been visited by a geologist, much less closely examined, and what can be seen from a distance tells, in my opinion, more against than in favour of the theory.

There still remain a few points which I should like to shortly discuss in connection with Diener's description. Of the exotic blocks observed by the expedition of 1892 some rest on Gieumal sandstone, others on Spiti shales and are either connected with igneous rocks or perfectly free from them. I may be allowed to point out how these features might have been brought about.

In cases where igneous rocks are preserved, we are not absolutely obliged to think of disturbances. Denudation of the country, previous to the terrestrial eruptions, might account for these instances. Such an explanation might, for example, be correct in the case of Peak Chirchun No. 1, which then would represent a patch of lava with a large exotic block involved in it, the whole resting on Spiti shales. The fact that these are much crushed and contorted below the peak

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[1] Indicated on pl. 11 by small crosses.

(Griesbach, l. c., p. 23) offers no objection to this hypothesis, as it may well have been brought about subsequently.

In cases where no lavas are recorded, they must either have been decomposed beyond recognition, the origin of the blocks being then possibly as pointed out above, or else such blocks have been isolated completely from the igneous rocks by disturbances, in a similar way as the large block No. 9 near Kiogarh Chirchun E G.

Thus I do not think that any of the facts recorded from the Chirchun area can be said to be in discord with the explanation I have given for the origin of the exotic blocks.

I therefore come to the conclusion that the exotic blocks of Johar and Chirchun have nothing whatever to do with the "Klippen" of Europe. Beyond a certain similarity in appearance no affinity can be discovered between them. While none of the European occurrences is connected with igneous rocks, their origin being according to all accounts due to structural causes, the exotic blocks of Tibet and the adjoining frontier districts are intimately connected with volcanics and owe their existence to volcanic action.

I am however well aware that no completely satisfactory solution of this problem has yet been obtained. Not only are the sources of discharge of the volcanics unknown, but also the facies of the exotic limestone blocks is still a mystery, which is far from being satisfactorily cleared up, and there are several other questions of no small importance which require further research in the field. It is earnestly to be hoped that it will some time be possible to survey in detail those uninhabited districts, which lie beyond the Indian frontier, for then only can we expect to completely unravel a problem, which is no doubt among the most attractive in Indian Geology.

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4. Upper flysch. ? Upper cretaceous.
    - 4*f*. Green and red tuffs.
    - 4*e*. Greenish sandstones
    - 4*d*. Black, siliceous shales.
    - 4*c*. Brown sandstones.
    - 4*b*. Black, crumbling shales.
    - 4*a*. Red and greenish shales and red earthy limestones.

3. Lower flysch ("Gieumal sandstone," Stol.) ? Lower cretaceous.

2. Spiti shales (upper jurassic).

1. Grey limestone mass, ranging from upper trias (dachsteinkalk) into middle jurassic.

L. Red lower liassic limestones (pl. 9).

D. Grey dolomitic limestones, probably chiefly dachsteinkalk.

P. Red and white permo-carboniferous limestones.

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A. von Krafft.

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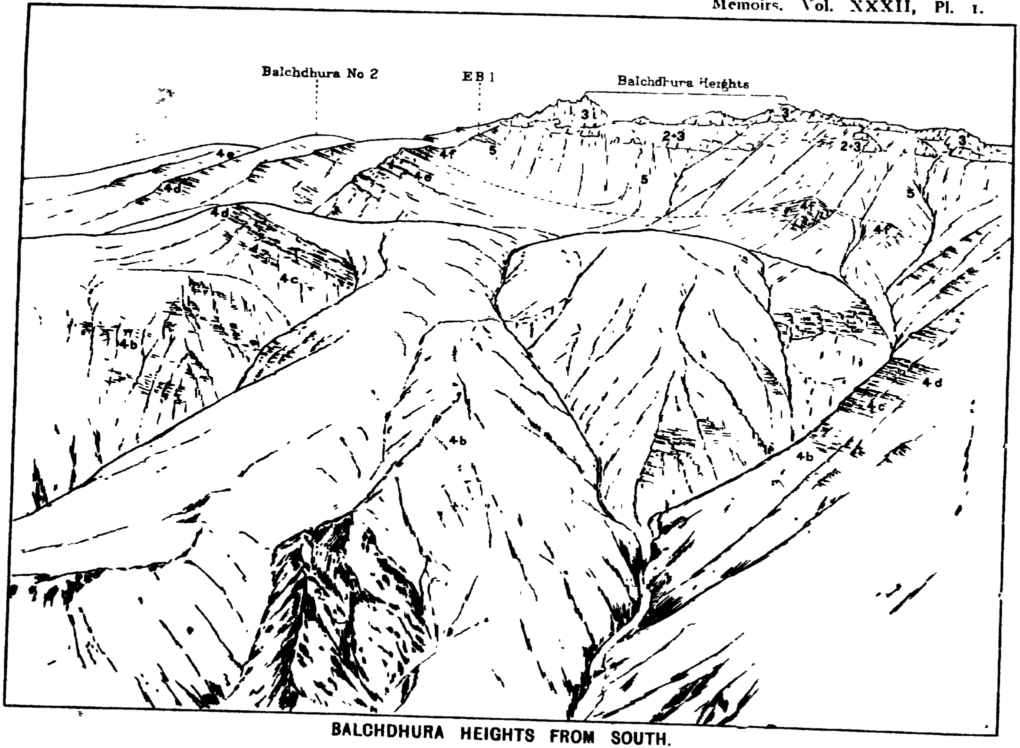
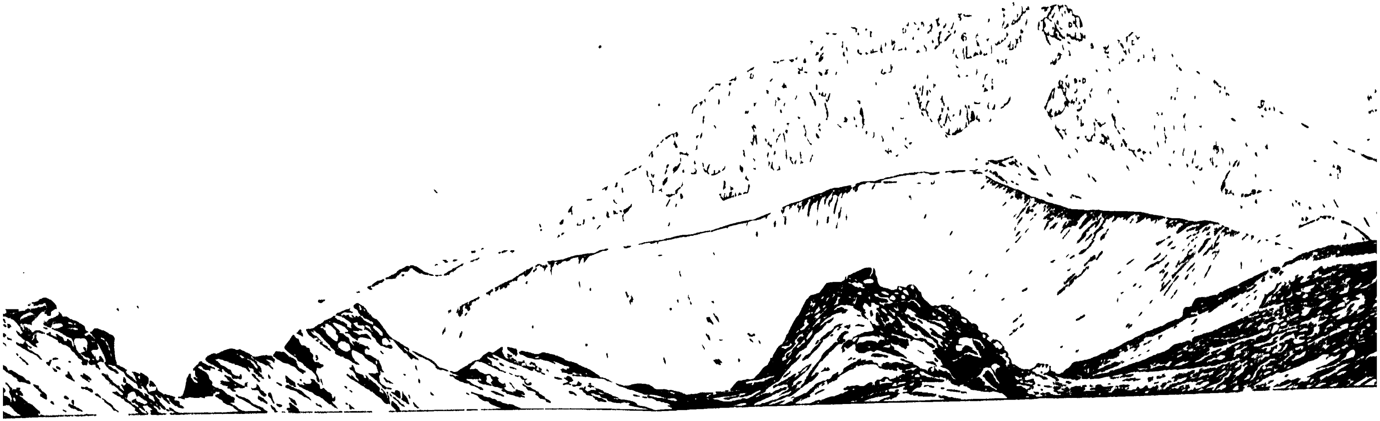


BALCHDHURA HEIGHTS FROM SOUTH.



KIOGARH HIGH PLATEAU FROM PEAK BALCHDHURA 18110.

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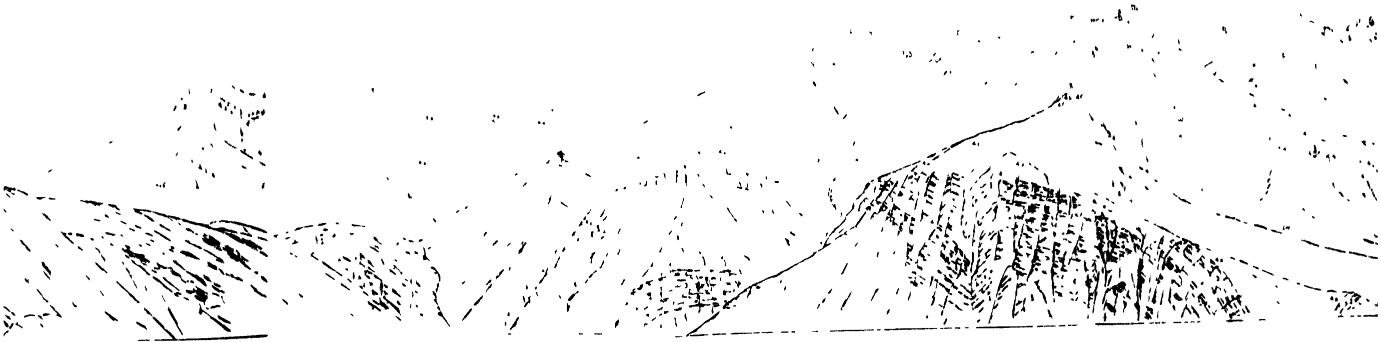

KIOGARH HIGH PLATEAU FROM RANGE S OF TALLA KIOGARH I. E G

OVERFOLD ON RANGE E. OF [illegible]

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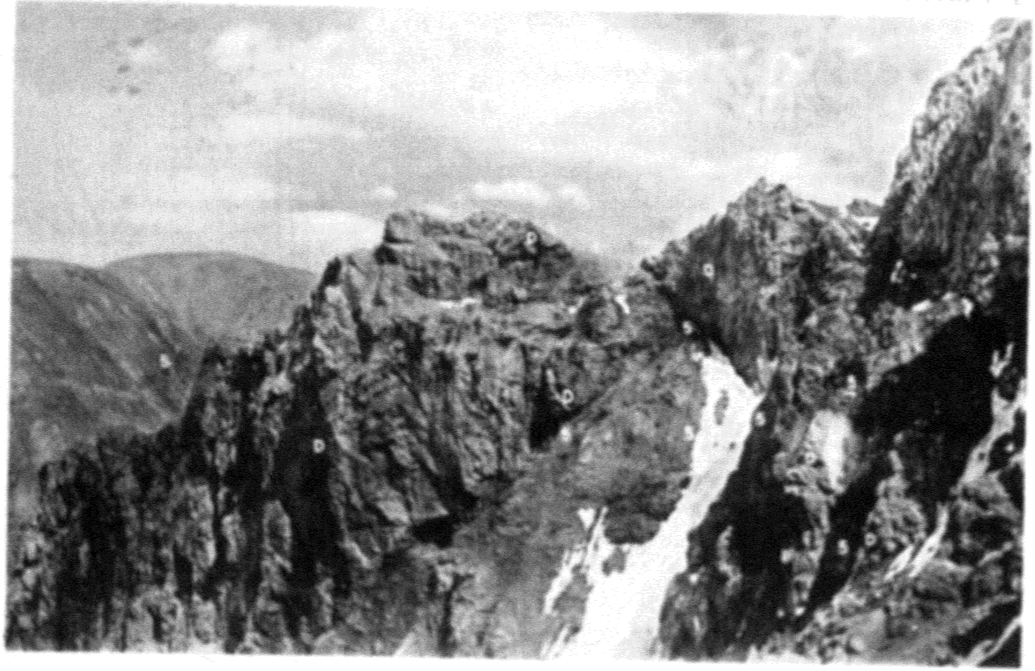

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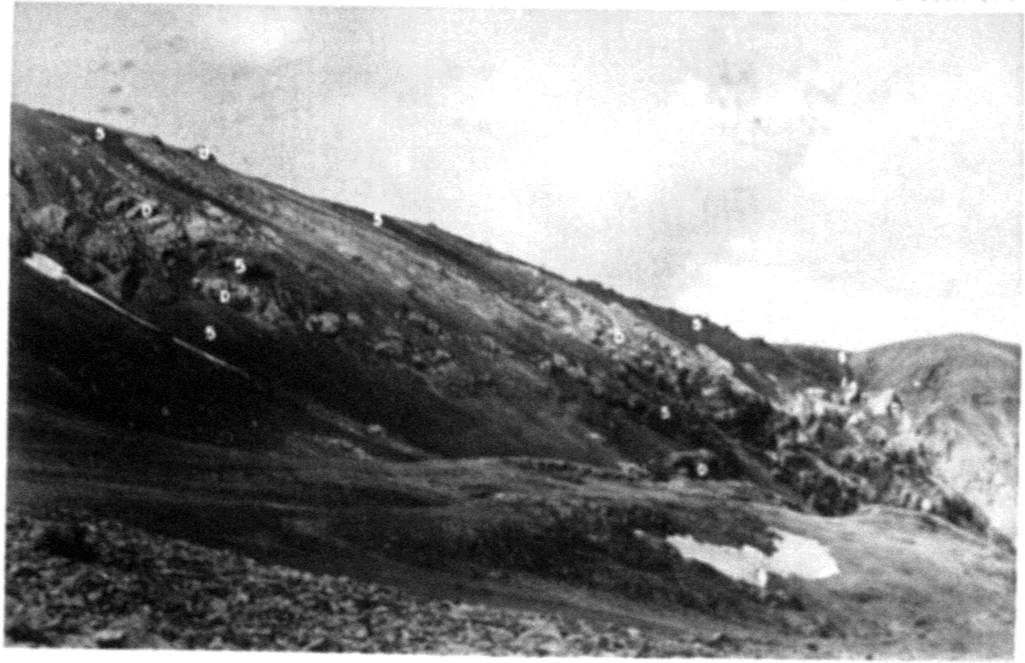
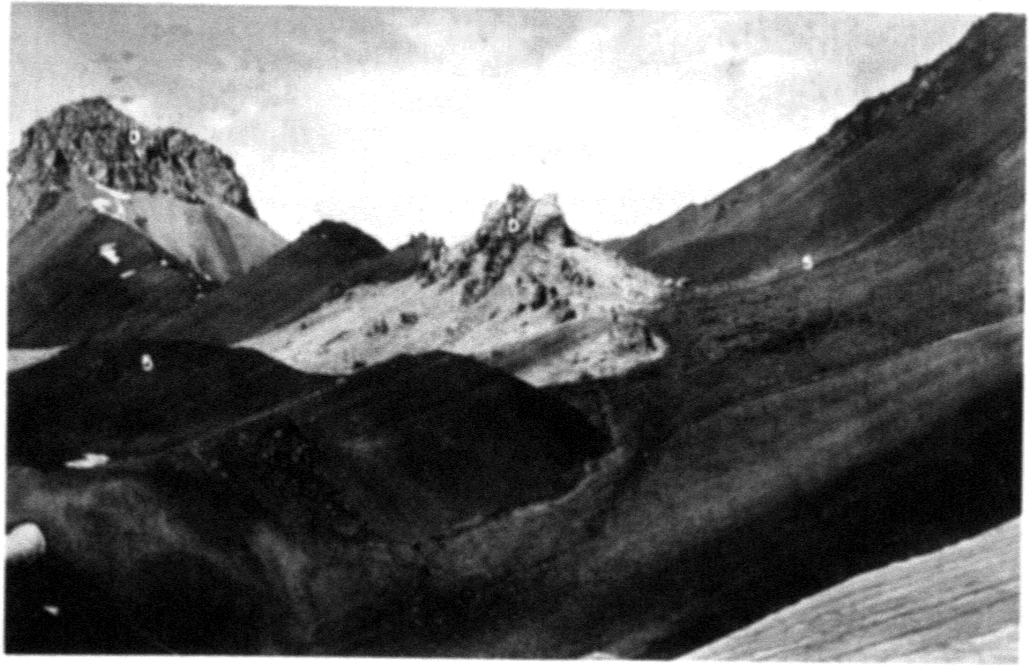
NORTHERN SCARP OF KIOGARH No. 1



EASTERN SLOPE OF KIOGARH No. 1, FROM S.W.

A. von Krafft



KIOGARH No. 5. AND EXOTIC BLOCK 8. FROM S.W.

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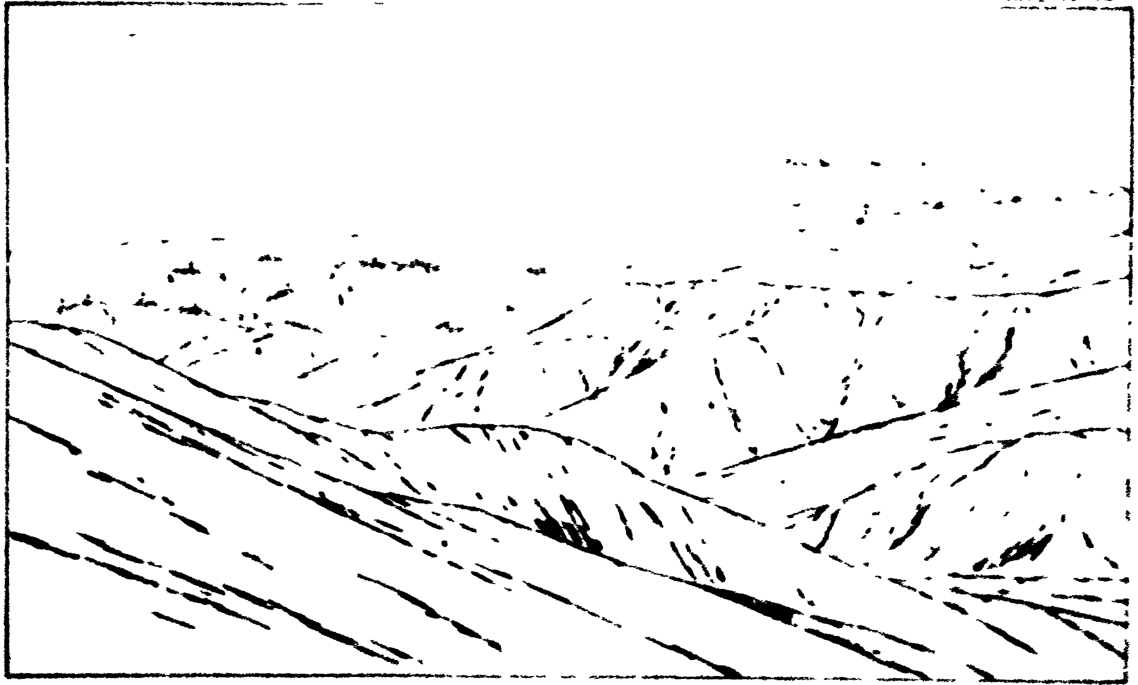

View from [illegible]

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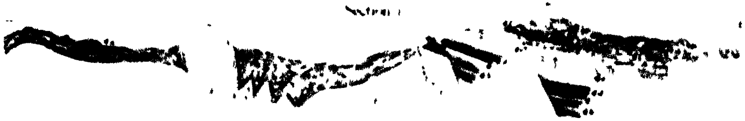
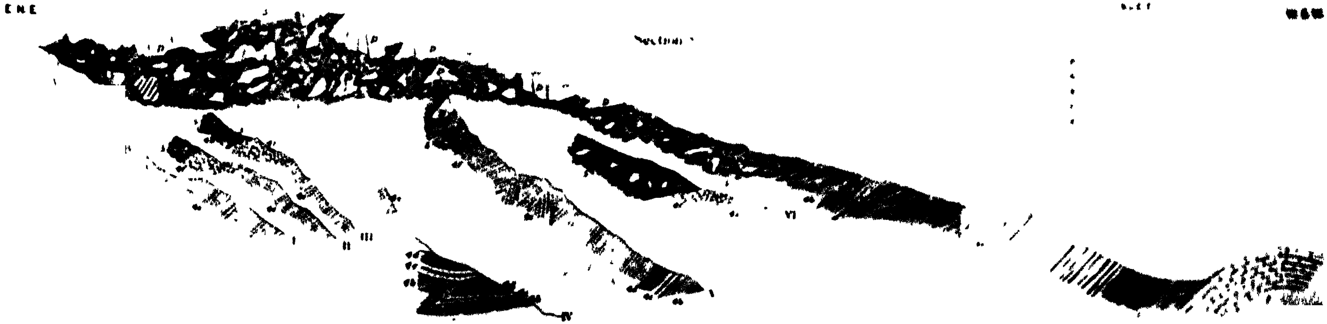


SECTION THROUGH BOUNDARY RANGE N OF KIOGARH RIVER.



SECTION THROUGH KIOGARH No. I AND ITS NORTHERN RIDGES.

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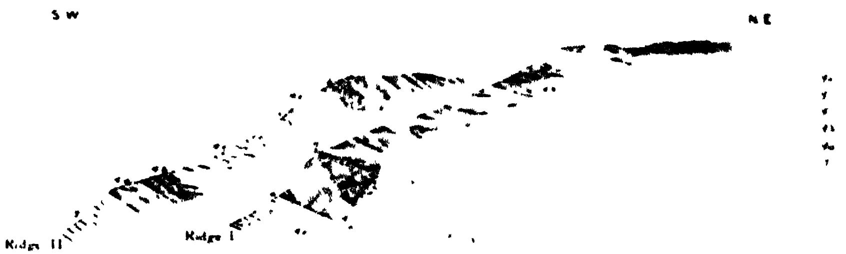
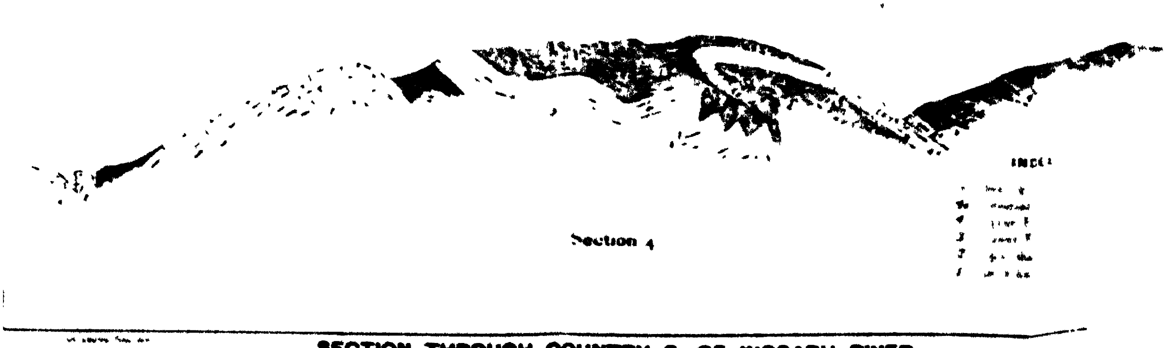
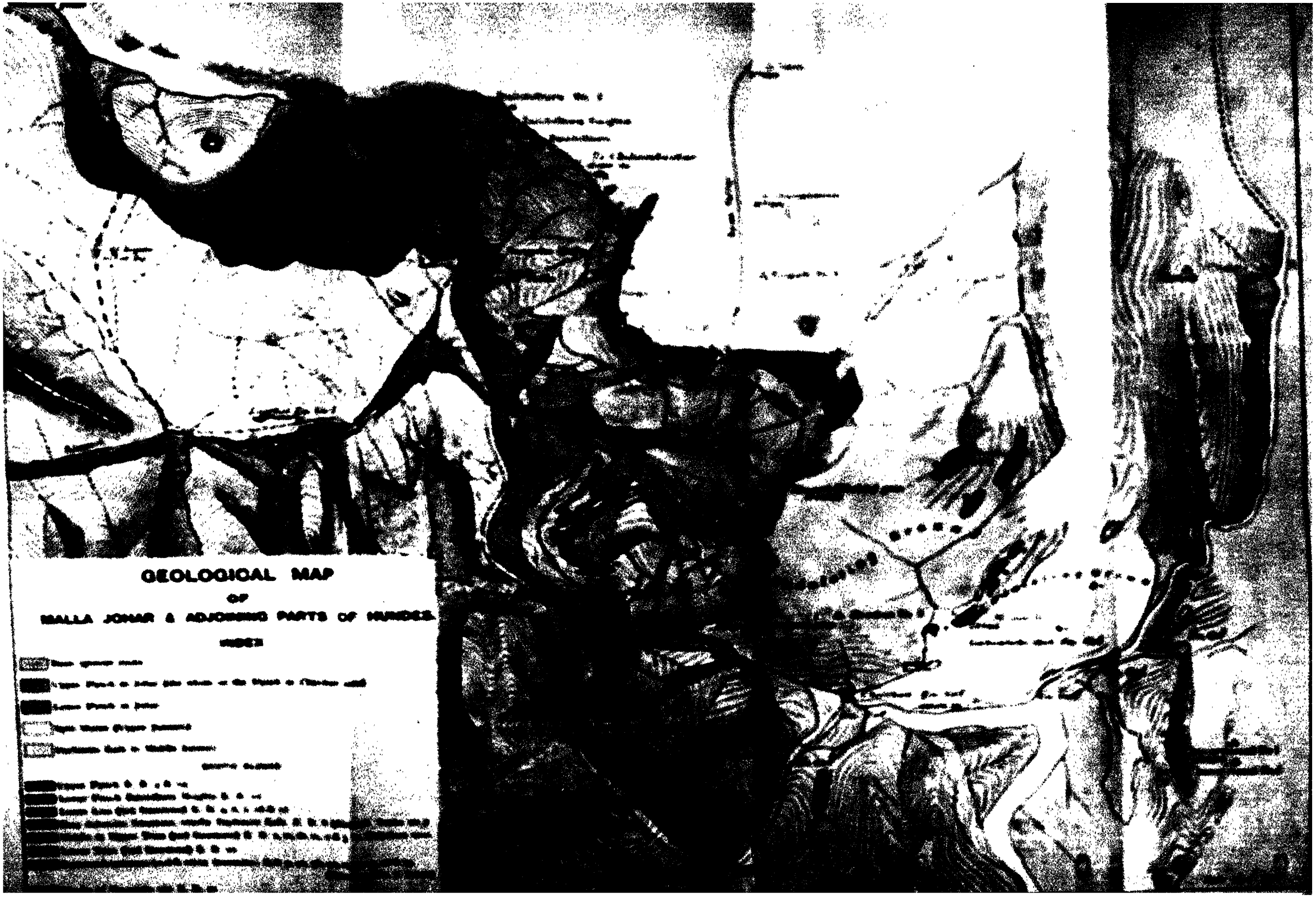


SECTIONS THROUGH RIDGES E & N OF KIOGARH CHIRCHUN E C



SECTION THROUGH COUNTRY S. OF KIOGARH RIVER.



GEOLOGICAL MAP
OF
MALLA JOHAR & ADJOINING PARTS OF HUNDES.
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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXXII, PART 4.

REPORT ON THE JAMMU COAL-FIELDS. *By* R. R. SIMPSON, B.SC., *Mining Specialist, Geological Survey of India.*

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MEMOIRS

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THE GEOLOGICAL SURVEY OF INDIA.

REPORT ON THE JAMMU COAL-FIELDS. *By* R. R. SIMPSON, B.Sc., *Mining Specialist, Geological Survey of India.*

I.

INTRODUCTION.

The principal coal-consumers in North-West India.

The most important of the coal consumers of North-West India is the North-Western Railway Company. During the year 1901 this Company used, for locomotive and other purposes, a gross total of 179,174 tons of coal. Of this amount 31·4 per cent. was obtained from the Company's own collieries at Dandot (Punjáb), and Khost (Baluchistán), the former producing 24 per cent. and the latter 7·4 per cent. The major portion of their coal supply—68·6 per cent.—was, however, obtained from the coal-fields of Bengal. Over considerable sections of the Company's lines the use of wood fuel obtains. This source of supply is, however, year by year being curtailed, owing to the increasing cost of wood due to the depletion of the forests adjoining the railway line. As a consequence the use of coal tends to increase.

Fuel equivalents

The following table shows the relative fuel equivalents of the various descriptions of locomotive fuel used on the North Western Railway. The figures arrived at were determined by the Company's own experiments in the year 1894:—

		Coefficient.	Equivalent.	
1 ton Giridih (Kurhurbaree) best steam coal.	=	1·25	0·80	English patent fuel.
1 „	=	1·10	0·90	English coal.
1 „	=	0·90	1·10	Bengal (Barákar) steam coal.

		Coefficient.	Equivalent,	
1 ton Giridih (Kurhurbaree) best steam coal.	=	0·78	1·28	Khost coal and patent fuel, including Shahrig coal.
„	=	0·64	1·56	Dandot, including Bháganwala coal.
„	=	0·45	2·20	Wood fuel.

Importance of the exploitation of local coal-fields.

The average cost of Bengal coal delivered at Ghaziabad, the nearest approach of the North-Western Railway Company's lines to Bengal, was, in 1902, Rs. 14-2-0. Of this sum Rs 11-10-0, or 82 per cent., represents freight charges. From the above figures it can be understood of how much importance it is to the industrial development of North-Western India that the local coal-fields should be exploited, and new sources of cheap fuel obtained. It is, therefore, not surprising that from time to time various attempts have been made to open up the well-known coald-eposits of tertiary age in the north-west Unfortunately, owing to the poor quality of the coal, and its irregular occurrence, only two (at Dandot and Khost) of these adventures have proved to be commercially successful For some years past the attention of the Jammu and Kashmir Durbar has been directed to the possibility of mining coal profitably from the long-known coal-bearing beds in the Jammu hills.

The proposed Kashmir Railway and its relation to the coal question.

The question has recently been forced into prominence by a revival of the old project for the building of a railway to connect the cities of Jammu and Srinagar; the idea being that the alignment of the projected railway might be arranged to tap the coal-bearing area, and open up a cheap source of fuel for use on the railway. The interdependence of the railway and the coal schemes has, however, been somewhat discounted by Mr. Weightman in his report on the Kashmir Railway, where he has shown that the use of Jammu coal at an estimated cost of only Rs. 9 per ton, as against Bengal coal at Rs. 22 per ton, would effect a saving representing rather less than one half of one per cent. interest on the capital estimated to be required for the railway. It, therefore, appears that the question of working the coal must be considered practically on its own merits.

II.

POSITION OF THE COAL-FIELDS.

Position.

The coal areas to be described—known as the Ladda, Sangar Marg, Mehowgala, Siró valley, Kálakót, and Lodhra coal-fields—lie between latitudes 33° and 33° 13′, and longitudes 74° 25′ and 75° 13′. They are situated in the State of Jammu, a portion of the territory of His Highness the Maharajah of Jammu and Kashmir, and within 35 miles of the boundary between that State and the Punjab

The general trend of the coal outcrops is from north-west to south-east and the south-eastern end of the Ladda coal-field lies some 21 miles north-north-east of Jammu, the capital city of the State, and the nearest approach of the North-Western Railway. The Sangar Marg field is geologically co-extensive with the Ladda field, but the areas are separated by the Chenáb River and have been dealt with separately in this report. The Mehowgala, Siró valley, and Kálakot fields are detached areas lying from 5 to 13 miles to the west of Sangar Marg. The Lodhra field is situated about 10 miles north-east of the Ladda area.

Physical features.

The general character of the country is mountainous (see Plates V to IX), varying from three to nine thousand feet in height above sea-level. The strike of the coal-bearing rocks does not conform to any of the main natural features of the country, but cuts obliquely across the hill ranges, which have a general east and west trend. At the same time, owing to the relatively soft character of the coal-bearing band compared with the sub- and super-jacent rocks, the coal outcrops are, as a rule, found in or near the stream beds.

The country is fairly well wooded, the most abundant tree being a conifer, locally known as *chir*, from which excellent timber for mining purposes can be obtained. Of other conifers, *cuchil* and *deodar* are found on the higher ground; whilst of the harder woods, oak, walnut and occasionally holly occur.

The only made road in the Jammu State runs between Jammu and Udhampur, a distance of about 44 miles, and this road passes within seven miles of the prospecting drives in Jungle gully.

III.

PREVIOUS OBSERVERS.

The area has been described generally by Mr. H. B. Medlicott in his "Note upon the Sub-Himalayan series in the Jammu hills" (*Records, G. S. I.*, vol. IX, pt. 2). The Sangar Marg, Mehowgala, and Sirô valley coal-fields have been described in detail by Mr. I. D. La Touche (*Records, G. S. I.*, vol XXI, pt. 2).

The possible economic value of the Ladda coal-field first attracted attention in October 1901, when Mr. J. Godwin, an officer in the Public Works Department of the Jammu and Kashmir States, commenced prospecting operations in the Ladda coal-field, which have been carried on under his supervision up to the present time.

In January 1902, Mr. A. Mort, Manager of Khost Colliery, Baluchistán, visited and reported on the Jungle gully portion of the coal-field His opinion was unfavourable.

In February of the same year, Mr. Osterloh, one of the Boer prisoners, took over the direction of the prospecting operations, and, during his stay of some seven months, considerably extended the area of the explorations. Although he has left no regular report, I gather from various sources of information that he was strongly impressed with the value of the Ladda coal-field.

Mr. Mort paid a second visit to the coal-field in June 1902, and a perusal of his report shows that his views were then considerably modified in favour of the existence and workability of the coal-seam over a considerable area.

In October of the same year, Mr. T. D. La Touche, Superintendent, Geological Survey of India, visited the locality and spent a few days in the Jungle gully area. In his report he expressed the opinion that the existence of a coal-seam with an average thickness of five feet had been proved over a horizontal distance of two miles, through a vertical height of 1,700 feet He drew attention to the possibility of the coal-bearing rocks being found at a reasonable depth and a more moderate inclination beneath the newer rocks to the south-west of the Jungle gully area, and he suggested that this might be tested by boring.

In December last, Mr. E. L. Hope, Manager of Dandot Colliery, spent three or four days in an examination of the coal outcrops and prospects between Jungle gully and the Anji valley, a distance of about nine miles. In an interesting and extremely practical report he expressed the opinion that a workable coal-seam extends over nearly the whole of this distance.

IV.

THE PRESENT ENQUIRY.

I arrived in Jammu on the 10th of March, 1903, and commenced an enquiry into the question of the economic value of the Ladda and Lodhra coal-fields—an enquiry which was completed early in the month of May.

Conference of Messrs. R. D. Oldham, E.L. Hope, and the Writer.

On the 28th of March, I was joined by Mr. E. L. Hope, Manager of the North-Western Railway Company's collieries at Dandot. On the 6th of April Mr. R. D. Oldham, Superintendent, Geological Survey of India, took over charge of the enquiry and remained on the ground until the 15th of that month. Mr. Hope left the coal-field a few days later. During the period of this association the coal question was thoroughly discussed, and I had the advantage of profiting by the intimate knowledge of Himalayan geology possessed by Mr. Oldham, and the practical experience of the working of thin and highly inclined coal-seams in India which Mr. Hope has acquired. Mr Hope had previously reported on a portion of the Ladda coal-field, and his supplementary report re-affirming his earlier views is attached as an appendix to this communication. On November 5th, I returned to Jammu and examined the coal-fields west of the Chenáb. I also paid a brief visit to the Ladda coal-field, and finally completed the enquiry early in January 1904.

Acknowledgment of assistance.

I take this opportunity to express my obligation to His Highness Sir Amar Singh, K.C.S.I., Vice-President of the Jammu and Kashmir State Council, and to Mr. Colvin, I.C.S., the Resident in Kashmir, for kindly assistance to me during my tours. Messrs. Godwin and Stewart, who superintended the prospecting operations, worked extremely well, and I have pleasure in thanking them for their good work.

Topographical map

The largest scale topographical map of the district available is the Atlas sheet, on a scale of 4 miles to 1 inch. Through the courtesy of the Kashmir Durbar authorities, I was enabled to secure an enlargement of this map on a scale of 2 miles to 1 inch, and the large map (Plate I) attached to this report is on that scale. It may be remarked of the original map (No. 29, Atlas sheet) that, whilst the position of the main ranges of hills, rivers, and streams appears to be accurate, the positions of many of the villages are not correctly marked. As far as these mistakes affect the position of the coal outcrops I have endeavoured to correct them, but such alterations cannot be considered to be more than approximately correct

V.

GEOLOGY OF THE LADDA COAL-FIELD.

Age of formations.

The geology of the coal area is, in a general way, fairly simple. The rock groups represented are grey sandstones and red clays of Murree age, apparently of great thickness, lying conformably on a thin but remarkably well-defined band of "coal measures" (Subáthu beds) made up of soft shales, interbedded with thin bands of earthy limestone of varying thickness, containing towards the base a seam of coal. The limestone bands occasionally contain nummulites. The shales are frequently carbonaceous in the neighbourhood of the coal seam, and towards the base of the group become strongly ferruginous, the bottom bed being a thin but remarkably persistent pisolitic ironstone band.

This group is the representative in this area of the Subáthu beds.

It has been deposited more or less unconformably on an ancient land surface of unfossiliferous limestone which has been considered to be of lower Mesozoic age. The base of this limestone group—the *great limestone* of Mr Medlicott *—is nowhere seen It is apparently of great thickness, but, in the opinion of Mr. Oldham, reduplication along thrust planes has taken place Bands of shales usually siliceous, and often flaggy, occur interbedded in the limestone. Veins of galena are found in it, and, in former times, were mined to some considerable extent

Folding

The whole of these rocks have been subjected to earth movements of considerable magnitude, acting apparently chiefly from the north-east The result has been that the beds have been ridged up into a series of anticlinal folds having their principal axes in a north-west and south-east line. These general features of disturbance are accompanied by both normal and reversed faulting. Local contortion is abundantly displayed, whilst in the soft Subathu shales the squeezing out of beds is by no means uncommon. It is owing to the denudation of the crowns of the anticlines that the pre-tertiary limestone and Subáthu beds are displayed at the surface. On account of the high dip of the beds (30°—90°) the coal-bearing rocks occur as a narrow band from three to six hundred feet in width, fringing the underlying limestone, and separating it from the overlying sandstones and clays. The relative ease with which these rocks have been denuded sharply distinguishes them from the adjacent groups, the drainage channels almost invariably following their outcrop. For the same reason their examination is rendered difficult by the frequency of landslips from the harder rocks. Similarly, the bold and rugged outline of the limestone slopes is seen to be in sharp contrast to the smoother and more rounded features of the sandstones and clays.

Although the *coal measures* are undoubtedly continuous between the outcrops in the different coal-fields, yet they are separated at the surface by a broad band of younger rocks, and it will be convenient for the purposes of this report to describe the areas separately.

---

* Records, G. S. I., IX, 2

The general section of the rocks, as seen between the village of Mootal and the Chenáb river, is as follows:—

Generalised section.

Formation.	Description.	Thickness in feet.
Tertiary. Murree group.	Grey sandstones and red clays.	Unknown.
Tertiary. Subáthu group.	Olive shales with thick bands of nummulitic limestone	50—100
	Olive shales with thin bands of nummulitic limestone	50—100
	Olive-brown shales	75—100
	Nummulitic limestone with thin bands of olive shales	25—50
	Olive shales, ferruginous	0—100
	Coal-seam, average thickness 2′7″	0'4—25
	Ironstone shales, often carbonaceous	7—32
	Ironstone	6—30
	Ironstone shales	10—30
	Ironstone, pisolitic at the base	6—30
Pre-tertiary.	Shales, yellow, olive, and dull crimson with ferruginous bands	0—300
	Siliceous grit	0—100
	Great limestone, dense, splintery, blue-grey in colour.	Unknown.

As described above, the principal geological feature of this area is that of a normal anticlinal flexure, broken and faulted on its steep southern scarp. From the accompanying map (Plate I) the outcrops can be seen to show a longitudinal waving, and to curve round the point of the anticline as its axis becomes depressed towards the south-east. To the south of the main anticlinal fault newer tertiary rocks cover the ground as far as Jammu City. They are much broken and faulted, and near the main fault itself inversion has taken place. For reasons which will be given later, it does not appear to be probable that workable coal will be found at a reasonable depth beneath the surface in this latter area. Section No. I, Plate IV, taken across the anticline between Sandráni and Santráni Kund (the line A. B. on the map, Plate I), will enable the geological features of the neighbourhood to be clearly understood.

Details of the Coal-bearing Formation.

Doodar ravine.

Commencing from the south-eastern point of the anticline a recognisable coal seam is first seen at Lain (33°0'—75°5') in the gorge of the Doudar river, about 400 yards above Doomwa, where the main stream is joined by the smaller Jungle stream. The position of the coal-seam, as recognized by Mr. La Touche in his recent report, is quite abnormal, since it is overlaid as well as underlaid by the *great limestone* (see Plate IV, section 2). The overlying limestone has apparently been forced up from below by a reversed fault running along the strike of the ironstone. The effect of this overthrust has been to cut out all but the lower members of the *coal measures*, and to crush and in places squeeze out even these. The ironstone and overlying shales can be seen in their true position at Doomwa, at the mouth of the gorge, but they are much contorted and broken up, and the coal-seam appears to be missing.

At Lain, at a point about 40 feet above the bed of the river, a level has been driven along the coal horizon for a distance of 285 feet. The ground passed through consists of lenticular patches of coal lying between the ironstone and the overlying limestone. The coal is accompanied by a stiff, grey clay, evidently the crushed representative of the upper shales. Frequently the limestone forms the roof of the coal seam, and for the major portion of its length the drive has been blasted out of that rock. Thirty-two feet from the inner end of the level the coal thickens out gradually into a somewhat regular seam which in the face exceeds 5 feet in thickness, the roof not being found.

The section seen in the face is—

Stiff, grey clay	2' 6"+?
Coal	5'+?

On the opposite side of the nala the Mootal level has been driven along the coal horizon in a south-westerly direction for a distance of 237 feet. This excavation had fallen in previous to my visit. It is said to have commenced in six inches of coal, which thickened to 10 feet at a distance of 51 feet, and decreased gradually to 2 feet at 101 feet. Beyond this point the limestone came down on to the ironstone, squeezing out the coal. The drive was continued in broken ground made up of boulders of limestone and sandstone (?) until 18 inches of coal was again encountered at 230 feet. This coal thickened to 25 inches at a distance of 237 feet, and the driving was then discontinued.

Passing up the slope from the Lain drive a thick coal outcrop is found on the crest at Lain, 250 feet vertically above the bed of the Doodar nala

The section here is:—

Olive shales, broken	?
Coal and coaly shale bands	20′ 0″
Coal	15′ 0″
Grey shales	10′ 0″
Ironstone	?

The dip at this point is 70° to S. 35° E. Some 70 feet further on, a trench, now fallen in, is said to have exposed, at a depth of 10 feet, from 10 to 15 feet of coal and shale, overlaid by 5 feet of shale, dipping 75° in a direction 50° east of south. Six hundred feet beyond, another trench, now collapsed, has proved the coal. The section is:—

Coal (at a depth of 20 feet), said to be	5′ 0″
Shales	65′ 0″
Ironstone	?

It may be noticed that the shales have thickened considerably, and that the dip has decreased to 58° in a direction S. 63° E.

At the mouth of the gorge at Doomwa, (33°0′—75°5′), where, as mentioned above, the *coal measures* are found in their true position, a pit was sunk on the coal horizon to a depth of 20 feet, and revealed only a few strings of coal in a mass of clay and broken limestone.

Jungle ravine.

Following up the Jungle stream the ironstone outcrop disappears under talus about 150 feet north-east of Doomwa, the stream bed being occupied by the olive shales and nummulitic limestone, which, with their overlying sandstones and clays, are much contorted and broken up. This disturbance continues for rather more than three-quarters of a mile. A short distance below trial trench No. I, the ironstone-outcrops, after passing over the high ground between the Doodar river at Lain and the Jungle nala, join the latter ravine and bend round to the north. At trial trench No. I, the ironstone can be seen to be slightly folded on the strike, this disturbance apparently representing the dying-out of the Deodar river fault. At this point a trench, now fallen in, is said to have exposed four feet of coal at a depth of 10 feet.

Continuing up the stream, the strike of the beds perseveres due north with small local bends, the dip being east at an angle of 45°. One thousand feet from trial trench No. I, a similar excavation, No. II, now collapsed, is said to have proved, at a depth of 8 feet, a thickness of 4 feet 6 inches of coal. The section at this point is —

Olive shales and nummulitic limestone	235'	0"
Coal	4'	6"
Ironstone shales with bands 3"—10' thick of ironstone, coaly in places	28	0"
Ironstone	5' to 7	
Great Limestone.	—	

Some 300 feet north the strike bends round to the north-west and continues on this line to the top of Gully pass (33°1'—75°5'). Some 400 feet beyond trial trench No. II, a long distance tunnel (Jungle A drive) was driven. At the time of my last visit this tunnel had advanced to a distance of 430 feet from its portal. After passing through a considerable thickness of detritus, coal was struck at 90 feet. Between 90 and 320 feet, coal and shaly coal, varying in thickness from 0 to 7 feet and averaging 1 foot 11 inches, was encountered. From 320 feet to 435 feet the coal, sometimes shaly in character, varied from 4 inches to 4 feet 3 inches, and averaged 2 feet 3 inches in thickness (see Plate XII, fig. I for graphical representation of thickness of coal-seam). A sample taken at a point 30 feet from the face, where the coal was 3 feet thick, gave only 11½ per cent. of ash.

About 2,100 feet beyond trial trench No. II, a flattened coal outcrop, 15 feet thick, is found. An inclined shaft (Jungle shaft) was put down here; but it had collapsed previous to my visit.

The following section is to be seen :—

Olive shales and nummulitic limestone	?
Grey-blue, shaly clay with limestone nodules	6'
Coal (said to thin out to 6 feet at a depth of 40 feet)	15'
Ironstone and ironstone shales, carbonaceous in places	10' to 15'
Great Limestone.	

The dip is to the north-east at an angle of 30°, but it is said to have increased to 45° in the shaft.

Three hundred and fifty feet beyond Jungle shaft the dip is 50° in a direction N. 50° E.; the section is as follows .—

Olive shales with bands of nummulitic limestone	68'+
Coal	ill defined
Shales with ironstone	20'
Ironstone	12'
Ironstone shales with carbonaceous bands	50' (?)
Ironstone	thin.
Great Limestone.	

A level (Jungle drive) was driven in at this point. Owing to the position of the coal in the stream bed, the excavation was commenced in the upper shales and curved gently round until the coal seam was struck at 62 feet. The coal was 3 feet 6 inches thick and thickened to 13 feet at 100 feet, gradually thinning to 8 feet at 118 feet In the last 30 feet of this length the strike bends round sharply to the north. As it was considered that the original strike would continue further ahead, and it being desirable to preserve the original direction of the tunnel, the workmen were brought back to the point where the strike changes, and continued to drive on straight ahead, in soft ironstone and clay, in the expectation of cutting off the corner. Coal about one foot thick was struck in the floor at 150 feet. A small quantity of inflammable gas (probably light carburetted hydrogen) was given off here. This gas, collecting in a cavity in the roof, ignited and caused a slight explosion, which singed the mine superintendent whilst he was making his examination. Since that time (November, 1902) the driving of this level has been discontinued. At the time of my visit I made a careful examination with a safety lamp, but was unable to find a trace of gas.

About 100 feet beyond Jungle drive, a parallel tunnel for ventilating purposes has been driven in for a distance of 50 feet; and at that point encountered a strike fault The throw of this fault has not been proved.

On my first examination of this locality, although I noticed that the rocks were much disturbed, I did not fully appreciate the actual geological conditions. On paying a second visit in company with Mr. Oldham, he pointed out that a considerable landslip has taken place at this point. This slip is fully 1,000 feet in length and has moved down on the face of the lower ironstone bed. Both Jungle drives and the shaft have been excavated in its crushed and broken fragments. For this reason the prosecution of these excavations has been discontinued.

Some 700 feet beyond Jungle drive the coal is again seen. Owing to the broken nature of the ground, it was not considered prudent to drive on the seam, and consequently a drive (No. A) was commenced in the lower shales, striking the coal at a distance of 105 feet from the commencement. The coal was found to be very loose and crumbling and its thickness was not ascertained. The excavation has since collapsed. The surface dip here is 40° in a direction N 40° E. This dip is preserved as far as and beyond trench B (1,100 feet from drive A) where, in an excavation, 8 feet deep (now collapsed), the coal seam is said to have measured 3 feet 6 inches in thickness.

About 450 feet further on, in an excavation (drive C), also fallen in, the same thickness of coal is said to have been proved. Drive D is 1,300 feet beyond drive C, and was commenced in the upper shales. Coal, 2 feet thick, was struck at a distance of 26 feet At 41 feet, ironstone came in The drive was continued for 70 feet further without striking coal This excavation is now closed.

At a point 100 feet south-east of D drive, a pit (No. I) was sunk on to the ironstone, at a depth of 26 feet. Rounded sandstone boulders lying on the ironstone, and the absence of coal, show that the pit has been sunk in talus. Two hundred feet beyond drive D, No. II pit was sunk, to a depth of 25 feet, with a similar result.

The most important prospect of all that have been made is drive E, situated 1,100 feet short of the crest of Gully pass. This tunnel was commenced in the upper shales, and struck coal at a distance of 70 feet. Between this point and the face of the drive, at 550 feet, the thickness of coal varied from 0 to 8½ feet and averaged 3 feet (see Plate XII, fig. 2 for graphical representation of thickness of coal seam). The assay of samples from this drive yielded ash varying from 22 to 42 per cent.

Two inclined shafts have been driven down in the coal seam, from the outcrop, and connected with E drive. In the first of them the coal was, at the outcrop, 6 feet thick, but between points 30 and 70 feet respectively from the start the seam thinned to 2 feet 6 inches in width, and then thickened to 8 feet. Between 70 and 85 feet (where drive E was holed into) the latter thickness continued. In the other shaft (Gully shaft), coal 6 feet thick was found for the first 40 feet of driving. Beyond this, and until the shaft joined E drive at a total distance from the outcrop of 97 feet, carbonaceous shales were encountered. The shaft was continued, on the full dip of the seam, for 45 feet below E drive. Throughout this distance an average thickness of coal of 6 feet was maintained. From time to time during the driving of the E tunnel and its shafts, small quantities of inflammable gas have been met with, and it was found necessary to introduce safety lamps into the workings.

At a point 37 feet beyond Gully shaft, a tunnel (drive F) was commenced in a coal outcrop 20 feet thick. This thickness became rapidly reduced, until at a distance of 35 feet the coal ran out. The barren ground continued to a distance of 146 feet. Between the latter point and the face of the tunnel at 302 feet the coal varied in thickness from 0 to 3½ feet and averaged only 9 inches (see Plate XII, fig. 3 for graphical representation of thickness of coal seam).

From drive F the coal outcrop can be traced for some distance up the nala, and it increases in thickness to 20 feet at a distance of 150 feet from the drive. Just before Gully pass is reached the ironstone bed can be seen to be much broken up by a series of small parallel faults, which cut diagonally across the strike and dip. This disturbance continues in a modified form right over the crest of the pass.

Between Jungle Gully and Sukhál Gully.

At a point 100 feet beyond Gully pass, a drive (Gully cutting) was made, and is said to have exposed from 2 to 2½ feet of coal overlaid by 5½ feet of soft coaly shale. This drive has collapsed

Gully pass is approximately 5,500 feet above sea level. From it the ground descends for 550 feet to Karáta Mill (33°1'–75°5'), in the bottom of the Doodar nala, and then rises steadily for about three miles to Sukhál gully at a height of 7,400 feet.

Nearly 1,000 feet beyond Gully pass, a tunnel (drive G) was commenced in the lower shales, passed through the lower ironstone, and is said to have found indications of coal, but shortly after collapsed.

Just before Karáta Mill is reached coal is exposed at the surface for some considerable distance. The general dip is 60° to north-east. The section at this point is:—

Olive shales and nummulitic limestone	?
Coal	6' 10"
Ironstone shales . . .	7'
Ironstone . . .	10'
Ironstone shales	20
Ironstone	10
Great Limestone.	

A cutting (Karáta No. 1), now fallen in, is said to have proved the coal to be 6 feet thick at a depth of 10 feet. Three hundred feet further on, the Karàta No. 2 cutting proved the ground to a depth of 20 feet, and is said to have found the coal seam to exceed 16 feet in thickness. At Karáta Mill a drive, 30 feet in length, is said to have proved coal 5 feet 6 inches in thickness.

From Karáta Mill the strike of the beds bends round to a course 75° west of north; the dip being north-north-east at an angle of 45°. Passing up the nala towards Sukhál gully the coal outcrop is seen to be covered up by landslips. Fragments of broken ironstone are to be seen here and there. No prospecting work has been done in this nala. About half a mile beyond Karáta Mill the rocks for some distance are seen to be contorted, the strike varying from 22° to 75° west of north.

A mile further on coal wash, two feet thick, in decomposed ironstone, occurs. The dip here does not exceed 35°.

About a quarter of a mile before Sukhál gully is reached traces of coal are found and continue right up to the top of the pass. Two hundred and fifty feet from the summit the coal seam is 2 feet 6 inches in thickness and is *overlaid* by ironstone. Evidently this is either not the true coal seam, or the latter has been repeated by a strike fault.

The Anji valley.

From Sukhál gully (33°2'—75°4') the ground descends 3,400 feet to the bed of the Anji stream, a distance of about 3½ miles. Passing downwards the strike trends round to 45° west of north. Traces of coal are to be seen all the way down to Santráni Kund (33°2'—75°3'), about one mile from the crest. At this latter place the coal seam is 2 feet 10 inches in thickness, and dips north-east at an angle of 30°. A drive, near here, struck the coal seam at a distance of 86 feet from the start. Between this point and the face, at 350 feet, the coal averaged 3½ feet, but is very impure (see plate XII, fig. 3 for graphical representation of thickness of coal seam). For fully three-quarters of a mile further fréquent exposures of the coal seam are found, but no exploratory work has been done.

About 2 miles below Sukhál gully the strike of the rocks sweeps round to the north, and the coal-outcrop becomes obscured by landslips and cultivated ground. In the bed of the Anji streams, the section exposed is :—

Murree sandstones and clays	Obscured by debris.
Olive shales and nummulitic limestone . . .	
Coal seam	
Ironstone	6'
Shales, ferruginous at the top	470'
Siliceous grit (about 100 feet)	
Great Limestone.	

The ironstone strikes N. 5° W., and dips east at an angle of 35°. In the limestone the strike is N. 40° E. and the dip south-east at 37°.

At Kotri (33°4'—75°3'), just across the stream, the strike of the beds sweeps round to the west and continues on this course until the Anji stream is re-crossed 3 miles below. Several prospects have been made at Kotri, but most of them, being commenced in broken ground, have collapsed. Three drives (Kotri No. I. *a*, *b*, and *c*), from 50 to 100 feet above the stream bed, were driven, respectively, 82, 40, and 45 feet, in loose ground, without finding coal. Kotri No. II drive, a short distance beyond, struck coal at a distance of 50 feet. At 57 feet the coal was said to exceed 7 feet in thickness, but the excavation has now fallen in. A companion drive (Kotri No. III) commenced in coal which thickened to 7 feet at a distance of 57 feet. This drive has also collapsed.

About a quarter of a mile further on, at Bowli (33°4′—75°3′), 450 feet vertically above the stream bed, the ironstone band is seen to be much contorted, and there are many evidences of disturbance. A drive (Bowli No. I) has been driven in near this point, for 20 feet, in soft coal exceeding 7 feet in thickness. About 500 feet beyond, an open cutting (Bowli No. II) was driven for a distance of 40 feet in coal more than 6 feet in thickness. The coal with its overlying shales dips 55° west of north, whilst 30 feet to the west the ironstone dips 75° east of north. Apparently these conflicting dips are due to surface slipping. Bowli No. III drives are 200 feet beyond No. II drive. Two drives were driven, respectively, 45 and 25 feet, in shales without finding coal. They are evidently some distance above the coal horizon. Still further on Bowli No. IV drive went 40 feet in shales containing coaly streaks. On the crest of the spur at Bourg (33°4′—75°3′), 825 feet above the Anji stream at Kotri, an open cutting has exposed a thickness of 6 feet of coal and coaly shale, striking north 78° west and dipping north at an angle of 52°. Just below this point a fault occurs—part of the old limestone being found overlying the olive shales and nummulitic limestone.

About three-quarters of a mile further west, and some 500 feet above the stream, the ironstone shales are found dipping N. 40° E., at an angle of 32°. An open cutting here (33°4′—75°2′) (Harruasu No. I) exposed 3 feet of decomposed coal. Some distance further west, two drives (Harruasu Nos. II and III) went 70 feet in the upper shales without finding coal. These prospects are quite evidently some distance above the coal horizon.

Rather more than a mile further west (in 33°4′—75°1′), a tunnel (Nadla No. III) was driven in and struck coal at 93 feet. From this point to a distance of 295 feet from the start the coal varied in thickness from 1½ to more than 9 feet, and averaged 4 feet 9 inches. At 295 feet a fault throws the measures to the south. After my last visit a crosscut in this direction was commenced, and I have since been informed that the seam, exceeding 9 feet in thickness, was reached after driving 30 feet. A sample from a point 265 feet from the portal of the drive, and where the seam exceeded 7 feet in thickness, yielded, on assay, 44 per cent of ash. The weight of the sample was about 40 lbs. and it contained about 1½ lbs. of large, pyritic nodules. These were rejected in the assay.

From Nadla No. III drive the outcrop of the *coal measures* descends rapidly to the Anji stream at a height of 3,550 feet above sea-level. The crossing takes place at the junction of the Tote and Anji nalas. Nadla No. I drive, on the north bank of the stream was driven 30 feet without finding coal. On the south bank a drive (Nadla No. II) has exposed a mass of coal exceeding 8 feet in thickness. The *coal measures* here are much disturbed, and dip towards the north only a few degrees from the vertical. The olive shales and nummulitic limestone have thickened to 535 feet, of which thickness fully one-half consists of limestone bands. Some 60 feet south of the coal exposure the *great limestone* can be seen dipping N. 70° E., at an angle of 30°. Apparently faulting has occurred.

For rather more than a quarter of a mile from here the *coal measures* follow the southern bank of the stream, but at Hákroli they bend round sharply to the north and again recross to the northern bank. Where the crossing takes place, coal is exposed on both sides of the stream. On the northern bank a trench (Hákroli No. I) (in 33°4′—75°1′) proved the thickness of the coal to exceed 6 feet. The dip at this point is 50° in a direction 45° east of north. At a point 50 feet beyond the trench, a drive (Hákroli) has been driven in to a distance of 180 feet. Throughout its length it is in débris, with the outcrop of the coal seam appearing occasionally in floor. As the thickness of cover increases the drive will doubtless run into solid ground. At the time of my visit the thickness of the seam could not be measured, and the coal appeared to be shaly.

Between the Anji and Chenáb Valleys

From the Anji stream at Hákroli the Subáthu outcrops rise steadily for 1½ miles, through a vertical height of 1,700 feet, to Punchári gully (33°5′-75°0′). The dip of the beds varies from 70° to the north to 30° to the north-east. Throughout the whole of this distance no coal exposures can be seen, the lower ground being covered by cultivated fields, and the higher ground by talus.

About a quarter of a mile west of and 350 feet below, the gully a good exposure of the ironstone and ironstone shales, dipping north at an angle of 40°, can be seen At this point, a trench on the coal horizon exposed a V-shaped mass of shaly coal, 2 feet thick, thinning down to a few inches. Apparently a wash-out occurs, the place of the coal being taken by yellowish-gray clay One hundred feet west another trench proved finely laminated, shaly coal, 3 feet thick, thinning to 2 feet, and dipping north at an angle of 80°. The surface dips hereabouts are extremely variable. About one-third of a mile further west, and just below the village of Bhurru, an outcrop of coaly shale containing bands of gray shale, the whole being quite 30 feet thick, can be seen. This outcrop is found 300 to 400 feet vertically below the assumed true position of the coal-outcrop, and it occurs doubtless in a slipped mass

From Bhurru the coal-outcrop (unseen) descends into the Bhurru nala (3,800 feet), and from thence rises for nearly a mile to Malkót gully (33°6′—75°0′) (5,150 feet). About one-third of a mile from the foot of the slope the dip of the rocks is 60° north-north-east, but gradually lessens to 40°. Shaly coal is again seen about half-way up the hill. A small excavation proved its thickness to be only 2 feet, and that th deposit is extremely irregular. Near the crest of the pass the dip o the rocks is reduced to 35° north-north-east. An excavation, jus over the summit, 5 feet deep, exposed soft, shaly coal exceeding 2 fee 6 inches in thickness. A little further down a trench on the co horizon went to a depth of 9 feet in loose earth. A borehole put dow

3 feet 6 inches further did not reach solid rock Passing downwards towards the Gogu nala the following section typical of the *coal measures* north of the Anji valley was measured :—

Sandstones and clays	—
Olive shales, with bands of nummulitic limestone, ferruginous at the base	250′
Coal	variable.
Shaly ironstone	6′
Shales with ferruginous bands	350′
Calcareous shales	50′
Great Limestone.	

The dip at this point is east-north-east, 45°. An excavation in the coal seam proved shaly coal exceeding 5½ feet in thickness. A little further on another prospect showed 5 feet of shaly coal.

From the Gogu stream (4,250 feet) the outcrop of the *coal measures* rises to Gagwáni gully (5,450 feet). About a quarter of a mile from the stream, coal is exposed over a length of outcrop of 100 feet. About the same distance further on coal is again exposed in several places, in one of which a pit, 8 feet deep, proved—

Shale	—
Clay	0′ 6″
Shaly coal	2′ 1″
Coaly shale	2′ 7″

The dip is north-east at 40°.

Half a mile beyond, at Gágwáni gully (33°7′—74°59′), the *coal measures* are much contorted, and a fine cleavage has been induced in the shales and coal. A pit, 9 feet dip, showed the coal seam to be 5 feet 4 inches in thickness. A second prospect in more disturbed ground near by proved only 2 feet of shaly coal.

Passing downwards towards the Chenáb river, coal is not seen for fully two miles. Just below Bakol (33°8′—74°58′) (2,950 feet), coal is seen in several places, but in very disturbed ground. The *great limestone* is found abutting against, and apparently overlying, the lower beds of the Subáthu group. The general dip of the rocks is south-east, but is locally extremely variable. Probably extensive landslips have occurred here. Three excavations were made in the coal outcrop, proving shaly coal exceeding 6 feet in thickness.

In the Batrare nala, about 1 mile north-east of Bakol, coal is again found, dipping at an angle of 40° to the south-east. The seam here is about 6 feet in thickness. Further down the slope, as the Chenâb river is approached, the Subâthu group is not seen, being overlaid by débris from the higher ground.

Between Mootal and Sandrâni.

Reverting to the Jungle gully area, the Subâthu beds, at Doomwa, curve round to the west as far as Mootal (32°59′—75°4′), where the Doodar river fault apparently dies out. Just north of Mootal, two trenches were cut in broken ironstone showing traces of coal. In the western trench, coal 2 feet thick, dipping northwards into the hill, was struck at a depth of about 15 feet. In the Ponhias nala, which debouches between Mootal and Chirai, a shallow excavation found traces of coal. Near the temple at Chirai, a cut, 11 feet deep, showed coaly strings in a broken mixture of gray-black clay and ironstone overlaid by broken, pre-tertiary limestone. Two hundred feet further west two trenches were cut and showed similar sections. About one hundred feet south of this point, Murree sandstones are to be seen dipping vertically.

About a quarter of a mile west of Chirai, a dip drive gave the following section, dipping north-north-east at an angle of 60°:—

Brecciated limestone		?
Ironstone	3′	6″
Grey shales with coaly streaks	4′	0″
Decomposed ironstone	1′	0″
Grey clay	2′	0″
Reddish sandy clay		—

Half a mile to the north-west another excavation in similarly inverted rocks proved coal from 3 to 6 inches in thickness. Four hundred feet to the west of this excavation, a horizontal drive showed the following rocks lying almost horizontally, but extremely irregularly:—

Limestone, broken	—	
Ironstone	6'	0"
Grey shale	1'	2"
Coal	0	9"
Grey shale	0'	10"
Red clay	4'	0"+

At a point 1,000 feet south-west of the last excavation, and 500 feet west of Sandráni, a small detached deposit of coal occurs. The section is:—

Brecciated limestone	10' 0"
Grey clay, containing bands of soft coal aggregating 2 feet in thickness, and a sub-angular block of ironstone, 4' × 4'	4'
Red clay	1' to 3'

This deposit is evidently derived from the outcrops further north.

About one-third of a mile west of Sandráni, a trench has exposed traces of coal in a stiff brown clay (probably decomposed ironstone) containing fragments of limestone.

In the Jagha nala, a little to the west, the Subáthu group is completely absent, the Murree beds abutting directly against the old limestone. All the way from Mootal no regular exposure of the Subáthu group occurs, the whole of the exposures showing broken and crushed rocks with frequent inversion. To the south, for more than three miles, is seen a steady succession of the Murree beds dipping from south-east to north-east at angles of from 25° to 45°. It is possible that folding with reduplication has taken place, but no evidence of such can be obtained owing to the absence of recognizable bands in these beds. Should such be the case, the coal, at certain points, may lie at a reasonable depth below the surface.

VI.

GEOLOGY OF THE SANGAR MARG FIELD.

Geology.

For a detailed description of the geology of the field the reader may be referred to Mr. LaTouche's report (Rec., G. S. I., Vol. XXI, part 2, page 62). It will be sufficient for me to say that the section of the *coal measures* is very similar to that of the Ladda field, the two areas being actually the east and west portions of the same field. The arrangement of the outcrops at the surface is, however, somewhat different, the simple anticlinal structure of the Ladda area being replaced by a system of anticlines and synclines which add considerably to the length of the outcrops, and would facilitate the exploitation of the coal. The general arrangement of the rocks may be apprehended from an examination of the map on Plate I, and the section (fig. 1) below.

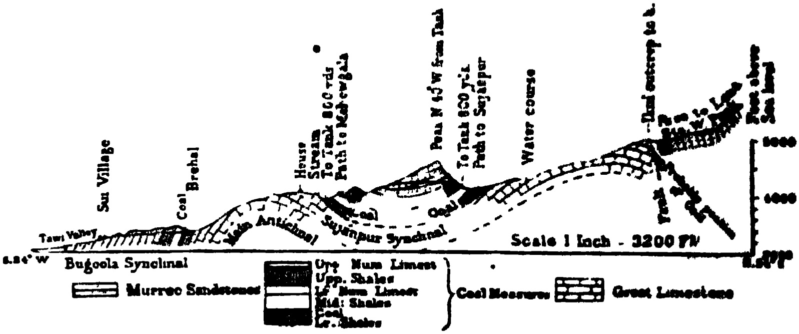

FIG. 1.—Section across Sangar Marg coal field from Brehal to Lena Stn., on line GH on Map, Pl. I.

The above is a reproduction from Mr. La Touche's report. It is taken across the western portion of the field in a direction transverse to the strike of the rocks.

The ground between the Chenáb river and Sangar Marg.

Details of the Coal-bearing Formation.—Commencing from the Chenáb river, where the description of the *coal measures* in the Ladda area was discontinued, the rocks for some distance continue to be obscured by landslips and talus deposits. Coal is first seen at Chimber (33°10′—74°57′), at a height of about 1,300 feet above the level of the river. A tunnel, 60 feet in length, was driven to prove the seam in depth. When first reached the thickness of the seam was 2 feet, but after ten feet of driving the thickness decreased to 1½ feet. The dip of the seam is to the north at a steep angle, and the quality of the coal is very inferior.

From Chimber the outcrops strike westward, and the horizon of the coal seam is not exposed, for fully three miles, until Kantan (33°11″—74°54′) is reached. At this point the dip of the measures is N. 15° E. at 40°. The outcrop of the seam is 4 feet thick. A tunnel proved the thickness, at a depth of 10 feet, to be 5¾ feet. After my departure, the tunnel was continued a few feet further, when the seam is said to have split up into two bands, respectively 18 inches and 6 inches in thickness. The quality of the coal is very inferior. Some time previous to my visit a tunnel had been driven in at a point about a quarter of a mile further west. It is now waterlogged. It is said to have been driven to a distance of 70 feet in coal thickening from 6 to 12 inches, and that the seam disappeared in the face. From Kantan the measures continue along the northern bank of the Chenáb through Arnás (33°11′—74°52′), and cross the Ans river. Throughout this ground the measures are not exposed.

To the south of the river and about 1½ miles south of Arnás, a small outlier of the *coal measures* is found at Salár (33°10′—74°51′). The beds extend from near the river up to Salár fort, 1,500 feet above the level of the river, and 3,000 feet above sea-level. The dip is to N. 10° E. at an angle of 30°. Over most of this ground the coal seam has been denuded. Coal is seen over an area of about one-third of a mile in diameter, but the seam is variable and does not follow the same horizon for more than a few yards. The thickness varies from 2 to 5 feet, and the appearance of the coal is poor.

Returning to the main outcrop, after crossing the Ans stream the measures enter the hilly country to the north of the Radd nala. Coal is first seen at Cherungha (33°11′—74°50′), where, in the bank of the Radd stream, a cutting, 10 feet deep, exposed nearly 9 feet of coal, of which the upper half is of fair quality. This outcrop can be traced for several hundred feet to the east, but westward is obscured by talus. About a mile further west a small cutting exposed about 2 feet of coaly shale, dipping nearly vertically. From this point the measures ascend to Baldánu gully (3,000 feet), from whence they descend for 1,000 feet into the Beddi nala, and again rise to Panásar (3,100 feet). On Panásar hill, coal outcrops are found in several places. Over a distance of about half a mile, four pits were sunk in the outcrops to depths of from 6 to 12 feet. The average thickness of coal proved was 6 feet, but it is little better than carbonaceous shale. The surface dips are very conflicting, probably due to landslipping.

In the Cheresu nala, about a mile west of Panásar, coal is again seen. A cutting proved the thickness to exceed 4 feet. A similar thickness was exposed in a cutting made at a point about a quarter of a mile to the west. In the Singar nala the coal can be traced for several hundreds of feet. A cutting, 8 feet deep, exposed the coal seam, 5½ feet thick, dipping N. 5° E. at 60°. On the western slope of the gully and about a quarter of a mile distant, two cuttings were made. In the first, coal 3½ feet thick was exposed, whilst in the second the section exposed showed two bands of coal, 12 inches thick, separated by a foot of shale. The dip is steep to the north. From here the measures can be followed through Behota (33°11′—74°45′) down to the Radd nala (2,200 feet). No coal is exposed. For about a mile the stream is followed, beyond which the beds run up the nala to the south of which lies Boni (33°11′—74°44′), to Paddar (3,400 feet). Near Boni a coal outcrop, 2 feet in thickness, is to be seen in ground which forms part of a landslip. On the way up to Paddar the measures are well shown. The shales, dipping vertically, are frequently contorted and occasionally contain coaly patches.

A little beyond Paddar the seam is again seen, dipping north at a high angle. A cutting, 10 feet deep, exposed 5 feet of inferior coal. Between Paddar and Gool (33°12′—74°40′) several cuttings and pits exposed shaly coal from 6 to 12 inches in thickness. In the village of Gool, at 4,650 feet, the seam is not less than 6 feet thick. At 5,000 feet a small cutting again exposed the seam. On the path to Ikni gully, at 5,400 feet, an irregular coal outcrop, 0—2 feet thick, is seen. On Ikni gully (33°11′—74°40′, 5,600 feet), coal is not seen, but about 100 yards to the north-west a thick coal outcrop is to be found. A tunnel was driven from a point below this outcrop, and struck coal at a distance of 108 feet. The seam is 6½ feet in thickness, and the dip is steep to the north. The quality of the coal is good, an assay yielding only 13 per cent. of ash.

The Ikni-Sujánpur slope.

From Ikni gully the measures slant down the southern slope of the range towards Sujánpur. At a point about a quarter of a mile west of the Ikni tunnel, at a height of 5,250 feet, a thick outcrop of coal is again to be seen. The dip is vertical. A cutting to a depth of 6 feet exposed a width of 13 feet of coal. Assay showed the coal to be of inferior quality. From this point as far as Sujánpur (3,500 feet), a distance of about two miles, the measures are only occasionally to be seen, and no coal is exposed.

The Sujánpur synclinal.

At Sujánpur (33°11′—74°38′) the *coal measures* bend sharply round to the east and run towards Chakka. About a quarter of a mile from Chakka (3,900 feet) a coal outcrop 15 inches thick is seen, but cannot be traced far. Near the tank at Chakka (33°11′—74°39′) the beds bend abruptly round the eastern end of the syncline and run west. At the bend coal is exposed in several places. A cutting, 9 feet in length, in the bank of a stream, at a point 550 feet north of the tank, exposed 18 inches of coal overlaid by 5 inches of coaly shale. This cutting is situated at a point 150 feet to N. 30° E. from a pit sunk by Mr. La Touche in 1887. This pit had been filled in, but I had the débris removed to a depth of 49 feet without finding the bottom of the shaft. The coal seam is found at a depth of 41 feet and is only 15 inches thick and overlain by 6 inches of carbonaceous shale. An assay of a sample from the coal in the pit yielded 27 per cent.of ash, or 6 per cent. less than the result yielded by the coal obtained from the cutting in the outcrop. About 1,000 feet west of the tank, a drive, 9 feet in length, proved 2 feet 10 inches of coal, which on assay yielded less than 7 per cent. of ash. Five hundred feet further west the seam has thinned to 15 inches, and this thickness obtains for about 1,000 feet further to the west, beyond which point the seam appears to die out. About three-quarters of a mile from Chakka, the measures sweep round south-wards over the top of the main anticline. No coal is exposed.

At Sarodabár (33°11′—74°42′), on the top of Sangar Marg hill (5,850 feet), a small outlier of the *coal measures*, occupying the head of Sujánpur synclinal, is found. The area over which coal is found is about a quarter of a mile in length and 150 yards in width. Coal is exposed in several places. A sample from an outcrop, more than 7 feet in width, yielded, on assay, nearly 43 per cent. of ash.

The Bugoola synclinal.

After passing down from Chakka over the top of the main anticline the coal measures again bend round to the east in the direction of Brehal (33°10′ -74°37′). At the bend, in the bank of a small stream, the coal seam is excellently exposed. It is 20 inches in thickness and dips 35° in a direction S. 20° W. Two hundred yards to north-west the thickness is only 12 inches, whilst 60 yards down stream an exposure shows 2 feet of coal lying almost directly on nummulitic limestone, and dipping south-west at 45°. This unusual position of the coal is probably only explainable by faulting.

At a point 150 yards to the east, a drive exposed 3½ feet of coal dipping south-west at 43°. One hundred yards further east the seam is 4½ feet thick, whilst about 80 yards still further east only a few inches of coal is found in vertical and contorted shales. About 150 yards further on, a cutting exposed a thickness of 7 feet of coal, dipping S. 10° W. at 30°. A fault of 3 feet throw, which occurs here, probably accounts for this increased thickness, for only a few yards away a pit, 18 feet deep, proved only 11 inches of coal dipping S. 20° W. at 50°. From Brehal, the outcrops ascend the slope to the north-east for about 350 feet vertically, and from thence descend steeply to the east towards the Tawi stream. At their highest elevation (3,350 feet), and at a point where the path from Ransu joins the path from Brehal to Chakka, coal is exposed. A cutting, 6 feet deep, proved 3½ feet of coal, which on assay yielded only 4½ per cent. of ash.

On the steep descent towards the Tawi stream, coaly traces are seen in several places. A large number of cuttings exposed shaly coal varying in thickness from a few inches to 2 feet. Near the Tawi stream, at 2,700 feet, the rocks are obscured by alluvium. Near the village of Ransu (33°10′—74°38′), and about one-third of a mile east of the Tawi, a pit, 10 feet deep, exposed 4 feet of shaly coal, dipping S. 25° E. at

75°. About half a mile further east, on the top of the ridge (3,400 feet) between Ransu and Kori (33°10′—74°39′), a cutting, 5 feet deep proved 15 inches of coal in vertical rocks. An assay of the coal yielded 28 per cent of ash. For fully three-quarters of a mile further east no coal is exposed.

At Kálamitti (33°10′—74°40′), the band of coal-bearing rocks bends sharply round the eastern end of the Bugoola synclinal, and runs back westwards. At the bend there is much disturbance of the beds, and coal is extensively exposed. In this neighbourhood, six cuttings and pits exposed coal varying from 2 to 6 feet in thickness. A sample from a cutting showing 2 feet of coal yielded 25 per cent. of ash, whilst 50 per cent. of ash resulted from the assay of a sample from a cutting showing 4 feet of coal.

In the steep nala leading westwards from Kálamitti, four cuttings exposed shaly coal from 1½ to 6 feet thick. Near the village of Kroo (on map 33°9′—74°38′), the *coal measure*-rocks curve round the western end of the old limestone ridge, which here forms so conspicuous an object in the landscape, and run to the east. On the village lands a pit, 17 feet deep, exposed 4½ feet of coal which on assay yielded 35 per cent. of ash. The dip is vertical. At a point 150 yards further east, cuttings proved from 2 to 4½ feet of coal. About a mile further on coal is again seen. It is shaly, and the beds are much disturbed. A little further east the *coal measures* are faulted down and disappear.

VII.

THE MEHOWGALA, SIRÓ VALLEY, AND KÁLAKOT FIELDS.

The Mehowgala field.

This field is situated some 8 miles west of Sangar Marg, in 33°12′— 74°32′. The coal measures occur fringing the edges of, and dipping away from, a central dome-like mass of *great limestone,* which, lying between the villages of Acker and Mehowgala, is about equally divided, on a north and south line, by the Aneari Taw stream, which passes through it in a deep and narrow gorge. Commencing on the north side, for about one-third of a mile to the eastward of the river

(2,500 feet), the measures are obscured by cultivated ground, beyond which, in the higher ground, coal is first seen. A cutting, 6 feet deep, exposed the following section :—

Coaly shale and clay	3'	0"
Coal	8'	0"
Coaly shale	1'	0"

The dip is to N. 20° E. at 65°. An assay of the coal from the 8 feet bed yielded 37 per cent. of ash

At a point about 500 yards to south east the seam is exposed in the high bank of the Ganoë stream. Two cuttings were made. The west cutting was driven 8 feet in a thick outcrop of soft coal of which the exact thickness and dip were not ascertained. Only 30 yards to the east the seam was found to be only 1½ feet thick, and lying almost horizontal. The coal removed from these cuttings being intermixed with pyrites, took fire spontaneously, and burnt with a choking sulphurous odour.

At a point 350 yards higher up the stream, a pit has been sunk during former explorations It was commenced in the shales overlying the coal seam, and, judging from the amount of spoil, must have gone to some considerable depth. Local tradition fixes the depth at about 100 feet, and does not record the finding of coal.

Some 500 feet south of the two cuttings last-mentioned, the seam was again exposed in a cutting, but the thickness is only 15 inches. One hundred yards to south-west, a drive, 10 feet long, proved coal, 2 feet 10 inches thick, dipping gently to S. 20° E. On continuing this tunnel to a distance of 14 feet, the coal gradually changed into soft shale containing thin threads of coal. One hundred yards to the west the coal seam, as proved in a 10 feet tunnel, is 3 feet thick; whilst about 50 yards still further west, the same thickness was exposed. From this point, the outcrops begin to descend towards the Aneari Taw stream, 350 feet below. About 50 yards from the highest elevation of the outcrop, a tunnel, 18 feet in length, was driven in coal thinning from 3 feet to 1 foot 10 inches, and dipping south at 20°. An assay of a sample from the face of the drive gave only 11 per cent. of ash. In a cutting 8 feet deep, some 400 feet further west, the seam is 2½ feet thick, and dips at 45°. Some 300 feet further on, a drive, 14 feet in length, was made in coal thickening from 2 feet 8 inches to 3 feet. The coal from this drive is hard and of good appearance. On assay it yielded less than 8 per cent. of ash. Thirty yards further on, coal is last seen, and from this point down to the Aneari Taw, about a third of a mile, the ground is covered by talus, whilst in the bed of the stream a considerable thickness of alluvial deposits obscures the outcrops of the *coal measures*.

Between the stream and the village of Mehowgala—about half a mile—the measures are not well exposed. In two or three places a coal band, 1 foot thick, is seen in the clays underlying the coal horizon. Just below the village, the outcrops attain their highest point (3,000 feet) west of the stream. Near here, a tunnel was driven on the coal seam to a distance of 13 feet. The seam dips north at 35°, is 19 inches thick, and assays only 6½ per cent of ash. One hundred and fifty yards to the east, a cutting, 8 feet in length, exposed coal exceeding 6 feet in thickness and dipping to the north at 20°. An assay of the coal yielded 8 per cent. of ash. From this point down to the Aneari Taw, on the east, a distance of about 300 yards, the *coal measures* are well exposed in the cliff, and coal is seen over practically the whole distance. As was occasionally observed in the Sangar Marg field, there are two seams, the upper of which varies from 6 to 12 inches in thickness, and lies about 20 feet above the lower or principal seam. The results of excavations in the lower seam, over this ground, may be summarized thus :—

Serial Number.	Distance driven, in feet.	Thickness of coal, in feet.	Dip.	Ash.
I	12	Exceeding 4		
II	21	½ thickening to 3		
III	6	2	35°	
IV	6	1¾	48°	12½ per cent.
V	12	5 thinning to 4	20°	
VI	7	2½		13 per cent.
VII	7	5½	45°	

The Siró Valley field.

About a mile to the west of Mehowgala, the *coal measures* are exposed in the broad and open valley in which Siró village (33°12'—74°30') is situated. The general dip of the beds is to the south at a very low angle. The horizon of the coal measures is only reached at the head of the valley, in the neighbourhood of Nimbal (33°12'—74°30'), at a height of about 2,700 feet above sea level. A great deal of coal is exposed on either side of the two streams flowing through the valley, and it is not easy to correlate the outcrops. As in the Sangar Marg and Mehowgala fields, there appear to be two seams, but there are many lenticular bands of less or greater thickness.

Following the path from Mehowgala, coal is first seen at Nimbal, on the left bank of the stream which flows down the eastern side of the valley. In a drive, 30 feet in length, the thickness was 4 feet, whilst in a shaft, 22 feet deep, only a few yards away, the thickness was 3¾ feet, thinning to 3½ feet at a distance of 5 feet from the pit. In a shaft, sunk in the fields on the western side of the stream, and about 500 feet distant, the seam, at a depth of 16 feet, was 19 inches thick. Five hundred feet further up-stream, a pit, 13 feet deep, exposed a thickness of 4 feet of coal. In the centre of the valley, at a point about 1,000 feet west of the excavation last mentioned, the following section was exposed in a pit 6 feet deep :—

Coal	0' 9"
Shale	0' 6"
Coal	0' 10"

On the right bank of the western stream, a good section exposes two seams of coal separated by 20 feet of shales. Short drives exposed 19 inches of coal in the upper seam, and 3½ feet of bright coal, overlaid by a foot of dirty coal, in the lower seam. About 100 yards up-stream, a cutting proved that the lower seam thins to 16 inches. In a branch nala, about 100 yards further north, the same seam is only 12 inches thick, but thickens to 2 feet, and further on is again seen with a thickness of 3 feet. About 100 yards down-stream from the point where the two seams are exposed in one section, a cutting in the left bank exposed the lower seam, 9 feet thick, but it thins in 10 yards to 1½ feet. On the opposite bank, the seam, with a fairly constant thickness of 22 inches, can be traced for about 150 yards down-stream. On the left bank again, and about 50 yards further down, the thickness is still 22 inches. The section, at this point, exposes the interesting examples of faulting illustrated in Plate XI. About 100 yards down-stream, a tunnel, 13 feet in length, in the right bank of the stream, exposed the upper seam with a thickness of 2 feet. Assays of six samples of coal from this neighbourhood yielded ash varying from 18 to 26 per cent., but another sample, from the upper seam, gave as high a percentage as 42.

The Kálakót field.

This field is situated about two miles to the west of the Siró Valley field, and is separated from the latter by a ridge of Murree sandstone which rises to a height of about 1,500 feet above the valley. The *coal measures* are exposed on all sides of a precipitous ridge of *great limestone* which cuts obliquely across the valley of a tributary of the Aneari Taw, and is some four miles in length. The width of this ridge varies from about one-and-a-half miles on the east to two or three hundred yards on the west. On the north and south, considerable local faulting has taken place, and the measures are much disturbed.

Coal is first seen at Kálakót (33°13′—74°28′), where a drive, 7 feet long, exposed 4 feet of coal, dipping N. 20° E., at 53°. Only 50 feet away, however, the seam is reduced to 14 inches. To the north-west, alluvial ground obscures the outcrops, but at Pirán (33°14′—74°27′), half a mile distant, the seam is again seen, 18 inches thick and dipping gently to north-east. About half mile further on a pit on the eastern slope of Jhaltutunia hill was sunk in coal to a depth of 14 feet. The thickness and dip of the seam were undetermined but the thickness evidently exceeds 8 feet. On the western slope of the hill, a good deal of coal is exposed. Two separate seams can be distinguished. The dip is S. 10° E., or towards the limestone, at angles of from 42° to

52°. Several excavations in the upper seams were made and a representative section of the exposures is:—

Inferior coal	1' 0"
Shale	from 2" to 1' 0"
Inferior coal	1' 0"

Over a distance of about 250 feet, three excavations in the lower seam, to a depth of from 10 to 14 feet, exposed from 2 feet 7 inches to 4 feet 3 inches of coal. Samples from this locality yielded from 12 to 17 per cent. of ash.

Between Jhaltutunia (33°14'—74°27') and the western end of the inlier a little west of Jigni (33°14'—74°25'), a distance of about two miles, four small pits exposed a considerable thickness of coaly shale with thin inconstant bands of shaly coal. At the bend of the outcrops round the narrow ridge of limestone the beds are much disturbed, and the dips contrary. A pit, 7½ feet deep and 5 feet wide, was sunk, all in coal, without finding the floor of the seam. Just below the village of Jigni, a cutting exposed 8 inches of coal, whilst half a mile further south-east only coaly shales are to be seen. At Kargála (33°14'—74° 26'), the measures are much disturbed and the coal appears to be patchy. A pit, 7 feet deep, exposed 10 inches of bright coal; whilst 600 feet further east, 4 feet of coal was measured in a pit 6 feet deep. Between Kargála and Sonjpir (33°12'—74°27'), a distance of fully 3 miles, the rocks are well exposed but the shales contain only occasional, thin bands of coal. A little north of Sonjpir, the measures dip south-west at from 15° to 20°. A cutting proved 2½ feet of coal overlain by 6 inches of coaly shale; whilst 200 yards to the south-east, two cuttings exposed about a foot of coal overlain by a foot of shaly coal.

At a point about a quarter of a mile before the stream is crossed near Ser, the coal seam is 23 inches thick, and dips N. 70° W. at 36°. At the point where the outcrops cross the stream, a little to the north of Ser (33°12'—74°27'), three cutting sproved coal, varying from 14 to 22 inches in thickness, and dipping S. 60°W. at 15°. At a point one-third mile to the east, the beds dip S, 15° W. at 25°. A cutting exposed lenticular bands of coal and coaly shale. Although the rocks are occasionally well exposed on the eastern side of the inlier, no coal is seen until the outcrops at Kálakót are again reached.

Seven samples of coal from this field yielded, on assay, ash varying from 11 to 33 per cent., and averaging rather more than 20 per cent.

VIII.

THE LODHRA COAL-FIELD.

Physical and Geological features.

Approximately parallel to, and some 10 miles north-east of, the Sangar Marg-Ladda anticline, another inlier of the old limestone and Subáthu beds is found.

This mass is 17 miles in length, and from one to three miles in width. It forms a lofty and precipitous ridge, cut through, three miles from its eastern end, by the Chenáb river. The following description is confined to that portion of the inlier lying on the left or south-eastern bank of the river.

As mentioned previously, the Ladda and Lodhra inliers are separated at the surface by a band of younger rocks. These rocks are extensively folded and in many places considerably contorted, the disturbance appearing to increase in intensity towards the north. It is possible that the Subáthu beds may be brought within a reasonable distance of the surface, at more than one point beneath them.

The Lodhra inlier, east of the Chenáb river, is three miles in length and one and-a-half miles in width. It is bounded on the north by the Madiál nala, and on the south and east by the Thansu and Lodhra ravines. On the south and east the Subáthu rocks are found crushed up, at high angles, against the limestone. On the north the group is missing, the Murree beds being faulted down against the limestone.

From Section No. 3, Plate IV, the somewhat simple geological features of the anticline can be clearly apprehended. From the general section, given below, it will be seen that the Subáthu group is considerably thinner here than in the Ladda exposures. It may also be pointed out that, in their turn, the Subáthu beds, at Ladda, are again thinner than the same group at Sangar Marg, as given in Mr. La Touche's section (*Records G. S. I.*, XXI, 2), pointing to a general decrease in the thickness of these deposits towards the north and east. The general section of the rocks is as follows:—

Formation.	Description.	Thickness in feet.
Murree	Grey sandstones and red clays	Thick.
Subáthu	Olive shales	5
	Nummulitic limestone	5
	Nummulitic limestone with many shale bands	50
	Olive shales	20
	Nummulitic limestone with thin shale bands	8
	Olive shales, carbonaceous at the base	15
	Shaly coal	2—8½
	Pisolitic ironstone	3
	Brown to red, ferruginous shales	10
	Soft calcareous shales	11
Pre-tertiary	Silicious breccia	0—30
	Great limestone	Thick.

Details of the coal-bearing formation.—The highest point to which the *coal measures* attain is Simni gully (33°9′—75°10′) (7,600 feet), from whence their outcrop falls away steeply on either side to the Chenáb River (3,000 feet).

The Lodhra and Madiál nalas.

Passing down eastwards from the gully, coal is first seen in the Lodhra nala about a third of a mile from the crest. As seen at the surface, the seam is 3½ feet in thickness, lies directly on the pisolitic ironstone band, and is overlaid by 8 feet of coaly shale. An excavation (No. 4), here, gave the following section, dipping south at an angle of 66°:—

Shale	—	
Shaly coal	1′	0″
Limy shale	0′	4″
Shaly coal	1′	1″
Limy shale	0′	4″
Shaly coal	3′	6″

Shale, coming in on the left side of the drive, displaced 1 foot 6 inches of the lower coal band. Numerous angular to rounded fragments of calcareous, coaly shale were found scattered through the coal bands.

About 100 feet down the nala a small thrust fault causes considerable disturbance. Two hundred and fifty feet east of No. 4 drive, a tunnel (No. 3) had, some time previous to my visit, been driven for 30 feet into the coal outcrop, and had collapsed. The overseer who superintended its driving stated that only coaly shale was encountered. A pit, sunk to a depth of 6 feet, showed that the tunnel had been driven above the coal seam. In the pit, 6 feet of shaly coal was proved. Two hundred and fifty feet further east, another collapsed tunnel (No. 2) is said to have been driven 30 feet in the coal. The thickness of the coal is said to have been 5 feet. A new cutting made at this point proved 5 feet of weathered, shaly coal. Two hundred feet still further down the nala, an old tunnel (No. 1), now partially fallen in, went 20 feet, and proved 4 feet of coal overlaid by 2 feet of ironstone shale, above which lie coaly shales. Five hundred feet beyond, a pit (No. 5) was sunk to a depth of 8 feet through the following beds :—

Shale	1′ 0″
Good coal	1′ 6″
Soft shale	2′ 0″
Coal	?

Owing to trouble with percolating water the sinking had to be abandoned. The rocks in the neighbourhood of this prospect are much disturbed. A dip to the south, at 75°, in a short distance alters to east at 60°. A little further on it flattens to 30°, and then increases to 48° to the south-west. From this point, although the ironstone outcrop can be followed, the coal outcrop is obscured by talus. Passing down to the junction of the Lodhra nala with the Madiál valley, the disturbance of the beds increases until just about at the debouchure (4,900 feet) the Subáthu group is faulted down and disappears. A mile down the Madiál valley, and half a mile below Madiál village (33°11′—75°11′) (wrongly marked on the Atlas sheet), the fault, striking north-west, is well shown in a spur north of the stream. The *old limestone*, dipping south-west at an angle of 85°, can be seen abutting against Murree sandstones, dipping N. 15° E. at an angle of 64°. Following down the ravine, the fault is seen to continue as far as, and beyond, the Chenáb River.

The Thansu and Kolri nalas.

Returning to Simni gully, traces of coal can be seen for some distance down the Thansu-nala. In one exposure, from 3 to 4 feet of coal is seen. Prospecting is rendered difficult by huge masses of débris fallen from the silicious breccia at the base of the old limestone. Half a mile below the gully, the stream falls vertically for 12 feet over the upturned coal outcrop, which, here, measures 8 feet 6 inches of soft, bright coal, and dips south-south-east at an angle of 56°. Passing down the nala, the *coal measures* are seen to be covered by cultivated ground.

Coal is again seen about 1½ miles from the gully (at 6,000 feet), and the outcrop of the coal seam can be traced for about 100 yards. The dip, at this point, is vertical An excavation in this outcrop gave the following section —

Coal . . .	1′ 0″
Irregular band of limy shale	0″ to 6″
Coal . . .	4′ 0″
Irregular band of limy shale	0″ to 6″
Coal, with limy concretions	3′ 0″

Below this point, the coal-bearing rocks are covered by talus from the limestone. One and three-fourths miles from Simni gully the limestone outcrop leaves the Thansu nala, rising some 700 feet up its northern slope to Kotaser gully (33°10′–75°9′) (6,050 feet). From the gully the crop descends steeply (at an angle of 30°) along the bed of the Kolri nala (33°10′—75°8′). The nala, right down to the Chenáb River (3,000 feet), is filled with débris which, in places, can be seen to exceed 30 feet in thickness. About one-third of a mile before the Chenáb is reached, the débris has been partially scoured out, and a portion of the coal seam exposed. An excavation, to a depth of 5 feet, in coaly clay, showed that all but 8 inches of the seam has been denuded. The dip here is to the south at 82°.

IX.

NATURE AND QUALITY OF THE COAL.

Physical characters.

The coal is extremely friable, slightly bituminous, and exhibits no regular bedding-planes or cleavage, but has a strongly marked foliated character. Parallel to the foliation planes it has a bright, lustrous, graphitic appearance, but a cross-section looks dull. It is very dirty and dusty. Its specific gravity is 1·42. It burns with little flame or smoke, the proportion of the fixed carbon to the volatile products being approximately as 3½ is to 1. The ash content is almost invariably high. The coal appears to be little affected by weathering. That from the drives on the Ladda slope cokes strongly if subjected to great heat. Elsewhere, the coal only occasionally exhibits coking qualities.

From its analysis, and trials that have been made, it appears to be a fairly good steam coal. Apart from its high ash content, the worst feature of the coal is its friability. When broken, innumerable shear-planes are seen to divide the mass into thin flakes. Consequently if subjected to the least rough usage it falls to powder. Placed in water a lump of the softer coal flies to pieces like fuller's earth with almost explosive violence. This crumbling nature is undoubtedly due to the mechanical pressure to which the *coal measures* were subjected at the time of the upheaval which resulted in these rocks being brought to the surface.

In the less disturbed parts of the coal-fields, where the beds are lying at a lower angle, the coal is occasionally fairly hard. Such localities are, however, few and far between. For the above reasons, therefore, it can be understood that, where the measures are highly inclined no hope can be entertained of finding harder coal in depth.

In this state of fine sub-division Jammu coal resembles the Mákúm coal from Upper Assam, which, partly for this reason, and also owing to the large amount of sulphur it contains, is specially liable to oxidation, and as a consequence to spontaneous combustion. This latter defect does not appear to attach to the Ladda coal, for I found no trace of heating in stacks from 8 to 10 feet high. In the Sangar Marg field, however, I noticed the occurrence of this phenomenon.

Small quantities of inflammable gas, probably light carburetted hydrogen, have been, from time to time, emitted from the coal in several of the prospecting drives.

Chemical composition and calorific value.

The quality of the coal varies within very wide limits, that from the outcrops between the Anji valley and Sangar Marg, and from the Lodhra coal-field being little better than carbonaceous shale. The following analyses of Ladda coal from the Jungle ravine were made in the laboratory of the Geological Survey of India, from samples sent down by the Kashmir Durbar officials some time previous to my first visit :—

	Gully.		Jungle.		Lala.	
	I.	II.	I.	II.	I.	II.
Moisture	0·87	0·21	12·94	0·37	2·49	1·70
Volatile matter . .	17·95	15·61	37·02	15·14	45·35	15·70
Fixed carbon . .	67·66	64·38	40·80	56·15	48·52	52·06
Ash . . .	13·52	19·80	9·24	28·34	33·64	30·54
Colour of Ash . .	Buff.	Light-grey.	Dark-brown.	Light-brown.	Light-buff.	Light-buff.
Caking properties .	Non-caking.	Cakes.	Non-caking.	Cakes.	Non-caking.	Non-caking.

Other analyses are as follows :—

	Dr. Schulten. Ladda Coal.	T. H. Ward, Esq. Ladda Coal.
Moisture	0·32	2·50
Volatile matter . . .	14·34	11·27
Fixed carbon	67·35	83·55
Ash	17·99	2·68

The whole of the samples, from which the above analyses were made, were probably carefully selected from the best coal.

The following assays are taken from Mr. LaTouche's report on the Sangar Marg and Mehowgala coal-fields :—

	From pit at Chakka, Sangar Marg.	From pit near Bagoola, Sangar Marg.
Moisture	0·55	0·17
Volatiles, exclusive of moisture .	11·48	8·67
Fixed carbon	45·50	39·13
Ash	42·47[1]	52·03
	100·00	

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[1] This high percentage of ash may perhaps be due to the admixture with the coal of the coaly shale band overlying the coal-seam.

[2] Agrees substantially with my own assay No. 62.

The following tabular statement gives the results of analyses made in the laboratory of the Geological Survey of India, by Sub-Assistant Hira Lal and myself, of a number of carefully-taken average samples collected by me from the outcrops and prospecting tunnels in the Jammu coal-fields.

Table of Analyses.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate I.	Remarks.	Moisture	Volatile matter exclusive of moisture and sulphur	Fixed carbon.	Ash	Sulphur.	Evaporative factor* by Thompson's calorimeter.	Colour of Ash.	Caking properties.
					THE LADDA COAL-FIELD								
1	Drive E, Jungle Gully.	80	Coal 1' 2" Dirt 0' 2" Coal 1' 3"	1		0·6	10·28	51·48	32·80	4·54	...	Light-grey	Cakes hard.
2				2	...	0·7	14·10	51·40	33·80	..	...	Greyish.	Ditto.
3	Ditto	150	Coal 6' 6"	40	433 feet from tunnel-mouth. Sample sent by Superintendent of prospects subsequently to my visit.	0·76	13·64	59·38	21·78	2·44	12·08	Ditto	Ditto
4	Ditto		... ...	3	Sample from coal shed.	0·76	14·84	44·80	39·60		8·80	Light-brown	Ditto.
5	Ditto	.		4	Sample from coal shed, rough washed.	0·72	15·50	51·08	32·70			Ditto.	Ditto.
6	Ditto	.		5	Sample from coal shed, fine washed.	0·64	16·38	58·98	24·00		9·42	Brownish-grey.	Cakes.
7	Ditto	...	......	6	Dirt and coal from samples Nos. 4 and 5.	0·66	13·70	34·06	51·58	...		Ditto.	Do.
8	Ditto	...	......	41	Coke made from coal from coal shed.	0·98	0·42	69·78	25·00	3·82	...	Brown	Hard dense coke.
9	Ditto	547 feet from tunnel-mouth.	Coal 3' 0"	94		0·52	16·62	41·26	41·60	.	..	Grey.	Cakes hard.

* Pounds of water evaporated per pound of fuel.

Table of *Analyses*—continued.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate I.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.	Colour of Ash.	Caking properties.
					THE LADDA COAL-FIELD—*continued.*								
10	Jungle A .	405 feet from mouth of tunnel.	Coal 3′ 0″	95	.....	0·46	17·94	70 14	11·46	.	11·87	Brownish-red.	Cakes hard.
11	F drive outcrop .	Outcrop	Coal 20′ 0″	39	Coked.	0·86	0·94	62·36	35·84	...		Light-brown.	Ditto.
12	Jungle drive .	30	Coal 1′ 5″	7	...	1·14	5·46	49 34	38·46	5·60	9 21	Brown.	Does not cake.
13			,, 1′ 8″	8	Contained an irregular clay band 4″ thick.	1·12	11·24	45·72	41 92	...		Ditto	Cakes slightly.
14			,, 2′ 5″	9		1·00	11·68	41 06	46·26	...	...	Ditto.	Ditto.
15	Sukhál Gully .	2	Coal denuded 2′ 6″	28	... .	1·78	11 62	39 74	46·86		...	Reddish-brown.	*Nil.*
16	Santráni Kund .	2	Coal 2′ 10″	27	......	0 76	30·38	35 06	33·80	...		Grey-white.	Cakes partially.
17	Ditto .	264 feet from mouth of tunnel.	Coal 4′ 0″ Shale 0′ 6″ Coal 0′ 6″	92	Sample from upper band.	1·30	11·56	25·60	61·54	...	.	Brown.	*Nil.*
18	Ditto .	366 feet from mouth of tunnel.	Coal 1′ 1″	93	....	0·48	9·66	47·86	42·00	...	7·63	Grey.	Cakes poorly.

19	Bowli No. I	10	Coal 2′ 0″	10	Sample sent by the Superintendent of prospects subsequently to my first visit.	1·32	9·96	27·28	61·44	...	...	Grey.	*Nil.*
20			„ 2′ 4″	11		1·22	10·68	26·38	61·72	...	...	Grey-white.	„
21			„ 3′ 4″	12		1·46	9·82	33·12	55·60	...	...	Ditto.	„
22	Nadia No. III	25	Coal 2′ 6″ Shale 0′ 6″ Coal 2′ 6″	42	......	1·22	8·18	74·27	11·88	4·45	23·10	Reddish-brown.	„
23	Ditto	265 feet from mouth of tunnel.	Coal 7′ 0″	91	A sample of 40 lbs. of coal contained 1½ lbs. of large pyritic nodules. These were rejected before assay.	0·38	8·38	47·24	43·80	...	...	Brown.	„
24	Nadia No. II	5	Coal 8′ 0″ +	13	.. ..	2·12	10·03	79·92	6·72	1·21	13·31	Ditto	„
25	Hákroli No. I	12	Coal 3′ 0″	14	...	1·20	6·78	48·07	30·50	13·45	...	Dark-brown.	„
26			„ 3′ 0″	15	......	0·96	8·24	57·24	33·56	...	...	Greyish-white.	„
27	Malkót	5	Coal 2′ 6″ +	16	.. ..	4·12	10·74	32·76	52·38	...	...	Brown.	„
28	Gogu nala	5	Coal 2′ 6″	17	...	2·34	9·46	19·12	69·08	...	...	Ditto.	„
29			„ 2′ 6″	18	...	1·78	6·94	18·14	73·14	...	...	Reddish-brown.	„
30	Riute	5′ 6″	Coal 2′ 1″	19	.. ..	1·32	7·96	29·28	61·44	...	...	White	
31			„ 2′ 7″	20	... ..	1·10	8·16	28·56	62·18	...	...	Ditto.	*Nil.*
32	Gagwini gully	7′	Coal 2′ 8″	21	.. ..	1·98	8·04	26·88	63·10	...	...	Brownish	
33			„ 2′ 5″	22	... ..	1·42	6·54	30·60	61·44	...	...	Ditto	*Nil.*
[illegible]	[illegible] Bahal	4	Coal 2′ 6″	23	......	4·06	8·98	16·56	70·40	...	...	Reddish-brown	
[illegible]			„ 3′ 6″	24	......	3·62	6·24	22·88	66·26	...	...	Light-brown	

* Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate I	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur	Evaporative factor, by Thompson's calorimeter.	Colour of ash.	Caking properties.
					THE LADDA COAL-FIELD—*concluded*.								
36	Bakol	4	Coal 3′ 0″	25	......	3'70	10'41	31'00	54'32	0'57	..	Dark-brown	*Nil.*
37			,, 3′ 0″	26		2 72	7'16	33'52	56'60	..	...	Brown	,,
					THE SANGAR MARG COAL-FIELD.								
38	Chimber	30	Coal 2′ 0″	43		1'40	7'74	26 74	64'12	..		Grey	*Nil.*
39	Kantán	5	,, 5′ 9″	44	Said to have thinned out to two bands 18″ and 6″ thick	1'32	3'42	27 46	67'80	..	..	Ditto	,,
40	Cherungha	3—6	,, 5′ 0″	45	....	0 74	5 96	69'50	23 80		11'87	Light-brown	,,
41		6—10	,, 3′ 9″	46	.. ..	2 70	8'30	55'40	33'60	...	...	Brownish-red	,,
42	[illegible]	0—8	,, 3′ 6″	47	..	1'12	9'83	9'48	79'52	.	.	Ditto	,,
43		8—12	,, 3′ 6″+	48	...	1'06	8'88	16'26	74'80	...	...	Dark-brown	,,
44	Ditto	3—9	,, 6′ 0″	49	....	1'04	7'88	21'48	69'60		..	Grey	,,
45	Ditto	2—5	Coal 3′ 0″	50	......	1'12	8'20	25'48	65 20			Light-brown	,,
			Shale 3′ 0″	...	Samples from coal bands.								
46		5—11	Coal 2′ 6″+	51	...	3'12	7'90	14'18	74 80	...	...	Brown	,,
47	Tálchenkót	Outcrop	,, 5′ 6″	52	.. ..	1'14	7'46	12'52	78'88		...	Reddish-brown	,,
48	Paddar	9	,, 5′ 0″+	53	...	1'10	8'02	22'14	68'74	...		Brown	

49	Sarodabár . .	Outcrop	Coal 3′ 6″	54		1·36	9·16	46·60	48·68	...	...	Ditto . .	”
50			Coal 3′ 6″	55	.	1·86	9·20	33·14	55·80	..	.	Ditto . .	”
51	Ikni . .	45	Coal 6′ 6″	56	...	0·62	10·34	76·00	13·04	.	14·11	Dark-brown .	”
52	Ditto .	Outcrop	Coal 6′ 6″	57	......	0·58	8·78	35·60	55·06	...	...	Grey . .	”
53			Coal 6′ 6″	58	...	0·76	7·70	30·00	61·54	...	.	Ditto . .	”
54	Chakka . .	7.	Coaly shale 0 5″ Coal 1′ 6″	59	Sample from coal band.	1·02	13·26	52·64	33·08	...	12·45	Light-brown .	Cakes.
55	Ditto . .	48	Coaly shale 0′ 6″ Coal 1′ 3″	60	Do.	0·72	13·56	58·76	26·96	..	12·69	Brown . .	”
56	Ditto . .	9	Coal 2′ 10″	61		0·60	11·59	77·06	6·66	4·29	15·35	Reddish-brown	”
57	Between Chakka and Brehal.	4	Coal 3′ 6″	62	..	2·50	13·98	79·06	4·46	...	14·74	Brick-red .	*Nil.*
58	Kehri . . .	4	Coal 5′ 0″	63		1·72	13·44	57·44	27·40	..	11·87	Ditto .	”
59	Ponm Camp .	3—7	Coal and pyrites 0′ 6″. Coal 1′ 8″ Shaly coal 1′ 6″	64	Sample from middle bed of section.	0·78	11·08	71·28	16·86	...	13·51	Grey .	Cakes hard.
60	Ransu . . .	10	Coal 4′ 0″	65	... .	2·68	9·92	11·68	75·72	...	...	Ditto .	*Nil.*
61	Between Ransu and Kori.	5 .	Coal 1′ 3″	66	...	17·40	20·14	34·22	28·24	...	.	Brown . .	”
62	Kálamitti . .	6	Coal 4′ 0″	67	.....	0·68	8·22	40·50	50·60	...	...	Grey . .	Cakes.
63	Kálamitti . .	7	Coal 1′ 11″	68	......	1·18	13·26	59·84	25·72	...	12·90	Light-brown .	Cakes poorly.
64	Kreol . . .	17	Coal 4′ 6″	69	......	0·72	13·62	50·60	35·06	...	...	Grey . .	*Nil.*

Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Pl. I.	Remarks.	Moisture.	Volatile matter, exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.*	Colour of ash.	Caking properties.
			THE MEHOWGALA COAL-FIELD.										
65	Ganot . .	6	Coaly shale 3′ 0″ Coal 8′ 0″ Coaly shale 1′ 0″	70	Sample from the middle band.	1·06	10·56	51·86	36·52	...	...	Brown . .	*Nil.*
66	Ditto . .	18	Coal 1′ 10″	71	......	1·02	12·52	75·20	11·26	...	13·34	Grey . .	Cakes poorly.
67	Ditto . .	14	Coal 3′ 0″	72	......	12·84	26·44	52·22	7·98	0·52	...	Brownish-red .	*Nil.*
68	Mehowgala .	7	Coal 2′ 6″	73	.. ...	0·78	12·04	74·14	13·04	...	13·31	....	Cakes poorly.
69	Ditto . .	6	„ 1′ 9″	74	......	1·48	11·76	74·20	12·56	...	13·31	Dark-brown .	*Nil.*
70	Ditto . .	8	„ 6′ 0″ +	75	......	2·80	11·94	77·50	7·76	...	13·72	Brownish-red .	„
71	Ditto . .	13	„ 1′ 7″	76	......	3·74	13·34	76·36	6·56	...	13·31	Dark-red .	„
			THE SIRO VALLEY COAL-FIELD.										
72	Nimbal . .	21	Coal 3′ 9″	77	Coal thinned to 3′ 3″ in a distance of 5 feet.	1·30	11·22	69·20	18·28	..	12·90	Brown . .	Cakes poorly.
73	Ditto . .	16	„ 1′ 7″	78	.. ..	0·60	11·70	61·92	25·78	...	...	Ditto . .	*Nil.*
74	Ditto . .	4	Shaly coal 1′ 0″ Coal 3′ 3″	79	Sample from the lower band.	3·00	9·52	66·12	21·36	...	12·49	Brownish-red .	

75	Ditto	6	,,	1' 7"	80	......	0·74	11·14	63·34	24·78	...	11·06	Light-brown	Cakes poorly.
76	Ditto	8-10	,,	2' 0"	81	......	0·70	8·14	73·01	12·06	6·06	13·72	Brownish-red	Ditto.
77	Ditto	0-9	,, ,,	4' 0" 5' 0"	82	Sample from lower band.	0·80	11·84	67·34	20·02	...	13·10	Ditto	*Nil.*
78	Ditto	13	,,	2' 0"	83	......	0·96	10·52	46·26	42·26	...	...	Brown	

THE KÁLAKÓT COAL-FIELD.

79	Kálakót	7	Coal	4' 0"	84	Thins to 14" in a distance of 50 feet.	0·86	10·00	78·48	10·66	...	13·51	Grey	,,
80	Jhaltatunia	14	,,	6' 0"	85	....	0·96	10·60	71·30	17·14	...	18·90	Light-brown	,,
81	Ditto	10	,,	2' 7"	86	....	0·80	6·41	78·00	11·50	3·29	15·15	Grey	Cakes poorly.
82	Jigni	7½	,,	6' 0"	87	....	2·58	7·76	56·74	32·92	...	12·69	Brownish-red	*Nil.*
83	Kargáli	6	,,	4' 0"	88	....	8·98	15·70	51·40	22·92	...	...	Red	,,
84	Sonjpir	2½	Coaly shale Coal	0' 6" 5' 6"	89	Sample from the coal band.	0·76	9·64	59·08	30·52	...	...	Grey	,,
85	Sar	Outcrop	,,	1' 8"	90	......	1·98	11·76	70·56	15·70	...	13·31	Grey to light brown.	,,

THE LODHRA COAL-FIELD.

[illegible]	Lodhra No. IV	6	Coal	1' 0"	89	......	1·32	10·96	13·20	74·52	...	...	Reddish-brown	,,
			Shale	0' 4"										
[illegible]			Coal	1' 1"	90	......	1·42	9·30	11·58	77·80	...	...	Brown	,,
			Shale	0' 4"										
[illegible]			Coal	5' 6"	31	......	1·30	8·82	13·22	76·56	...	...	Ditto	,,

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* Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

THE LODHRA COAL-FIELD—*concluded*.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Pl. I.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.*	Colour of ash.	Caking properties.
89	Lodhra No. V	...	Coal 1′ 6″	32	... ..	0·68	6·58	54·60	32 20	6 62	. .	Reddish-brown	*Nil.*
			Shale 2′ 0″										
			Coal ——										
90	Kolri	5	Coal (denuded) 0′ 8″	33	.....	0·82	9 64	49·26	40 28	...	...	Brown	”
91	Thansu nala	6	Coal 1′ 0″	34	. ...	1·54	7·72	17·46	73·28		...	Ditto	”
			Shale 0′ 6″										
92			Coal 4′ 0″	35	.	1·62	8·70	17·80	71·88	...	.	Ditto	,
			Shale 0′ 6″										
93			Coal 3′ 0″	36	...	1·10	8·22	18·02	72·66	...	...	Grey	”
	Thansu nala	5	Coal 2′ 0″										
94			” 3′ 3″	37	... ..	1·32	7·46	32·42	58·80	...	...	Brown	”
95			” 3′ 3″	38	......	1·50	7·54	30·60	60·36	...	...	Ditto	”

In the above table the following features stand out prominently :—

(1) The coal is extremely variable in quality, the samples from the outcrops between the Anji valley and Sangar Marg, and from the Lodhra coal-field being little better than carbonaceous shale.

(2) The volatile content is almost invariably low.

(3) The sulphur content is somewhat high.

(4) The coal is only occasionally of a caking quality.

Burning Tests.

A reference may be made here to a series of comparative tests of Bengal coal, firewood, and Ladda coal.

The tests were made in the water-tube boilers at the Jammu water-works. The boiler draught was induced by steam jets placed below the fire bars. The briquettes used in the experiments were made from Ladda dust coal and rice paste, were compressed in a small hand press, and were sun-dried. They had the following composition :—

Dust coal	100 parts.
Rice meal	2½ ,,
Water	1½ ,,

They were extremely soft, and crumbled easily through the fire-bars. The following table gives the details of the tests :—

Summary of comparative burning tests at Jammu waterworks.

Serial number.	Coal from	Variety of fuel.	Spacing of fire-bars.	Maunds burnt per hour.	Stoking details.	Percentage of ash and cinder.	Heat value, Bengal coal being 1	REMARKS.
1	Bengal .	Hard lump .	⅜"	2·43	Thrice during 8 hours.	26¼	1	
2	...	Selected hard, dry firewood.	⅜"	6·01		..	0·40	
3	E. drive .	3"—6" lumps	⅜"	2·66	,,	23½	0·91	
4	,, .	⅜"—2" nuts .	⅜"	2·66	,,	36¼	0·91	
5	,, .	Briquettes .	⅜"	3·83	Every hour	39¾	0·64	
6	Lain drive	3"—6" lumps, soft.	⅜"	4·69	,,	43⅜	0·52	
7	,, .	Briquettes .	⅜"	3·91	,,	29¼	0·62	Coal dropped through the fire-bars.
8	Jungle drive	,,	⅜"	5·06	,,	33⅜	0·48	
9	,, .	Coal dust .	$\frac{3}{16}$"	7·20	Thrice every hour.	61	0·34	

During the last six months a number of experiments have been made with Ladda coal in the locomotives on certain sections of the North-Western Railway. Through the courtesy of the Manager, Mr. S. Finney, I have been supplied with details of the trials, which are given in a condensed form in the subjoined table. For purposes of comparison the details of trials with Dandót and Bengal coal are also given.

Details of locomotive trials with Ladda, Dandót and Bengal coal on the North-Western Railway.

Serial No.	Date.	Runs were between	Miles run.	Average speed in miles per hour.	Average weight of train	Description of fuel.	Pounds of fuel used per ton-mile.	Pounds of water evaporated per pound of fuel.	Remarks.
1	8th to 13th July, 1903.	Lahore and Lala Musa.	493½	22·5	353	Ladda coal 94 % Pitch in briquettes 6 %	0·11	6·53	No clinker.
	3rd to 5th and 7th September, 1903.	Lala Musa and Kundián.	628	25	259	Ditto.	0·15	6·52	
	12th to 19th July, 1903.	Lahore and Lala Musa.	493½	21·5	336	Ladda coal 96 % Meal 3 % Lime 1 % in briquettes .	0·16	5·11	Briquettes extremely fragile. After rain a stack of 10 tons was reduced to pulp. Clinkered slightly
	2nd to 17th July, 1903.	Ditto .	493½	23	300	Ladda coal 97 % Lime 3 % in briquettes .	0·17	5·06	In transit from factory at Harampur to Lala Musa (51 miles) 25% of the briquettes crumbled to dust. During trial 10% of specially-selected briquettes crumbled to pieces. Clinkered badly.
5	23rd January, 1904.	Lala Musa and Makarwál.	45	19	230	Ladda coal 92 % Pitch 8 % in briquettes .	0·34	3·45	Coal and clinker obstructed fire bars. Average steam pressure only 80 pounds per square inch. Two hours' time were lost on run. Briquettes extremely soft and much worse than those with 6% only of pitch. 30 % crumbled to dust during transit from factory.
6	20th to 28th July, 1903.	Lahore and Lala Musa.	493½	21·5	329	Dandót coal 92 % Pitch 8 % in briquettes .	0·18	4·57	Trials made in wet and windy weather. Clinkered badly.
7	4th March, 1902 to 27th June, 1903.	Lahore, Phillour, and Lala Musa.	3,040½	24·4	306	Coal from 15 Bengal collieries.	0·136	6·08	

The briquettes of Ladda and Dandót coal used in the trials were made in the North-Western Railway Company's briquette factory at Haranpur.

As far as actual fuel consumption is concerned, Ladda coal, except in test No. 5, showed up exceedingly well. In every test, except the one just mentioned, it was superior to Dandot coal, and in one test it was actually considerably superior to Bengal coal. Great trouble was, however, experienced in burning the coal properly owing to the fragility of the briquettes, and this became so accentuated in the final test (No. 5), when briquettes made with 8 instead of 6 per cent. of pitch were used, that the experiment had to be abandoned before one-third of the contemplated run had been completed. The engineers who conducted the trials subsequently gave it as their opinion that unless some more suitable binding agent can be employed Ladda coal is unfit for steam-raising purposes in either locomotive or stationary boilers. This severe verdict is no doubt justified by the trials, but I am distinctly of the opinion that a suitable bond can be found. I would draw special attention to my No. 9 experiment in the table on page 242 in which a mixture of 95 per cent. coal and 5 per cent. wheat flour was used. Bulk experiments might be made with this bond, and with a composite bond of pitch and wheat flour. Again, seeing that briquettes made with 6 per cent. of pitch were so much superior to those made with 8 per cent. of that material, it would be interesting to see if a further improvement might result from a still further reduction of the percentage of pitch.

Briquetting.

From its finely divided condition there is considerable difficulty in using Jammu coal in the ordinary fire-grates of steam boilers. It will, therefore, probably be found imperative to compress the coal into briquettes. For this purpose, owing to the small amount of bituminous matter and moisture contained in the coal, some binding material will be necessary. Such bond should add as little as possible to the already high ash content. Probably pitch would be the most suitable bond, but unfortunately it is a somewhat expensive one.

With the object of utilizing some cheaper material, I have made a number of briquetting experiments with different binding materials. The coal used was passed through a screen with apertures $\frac{1}{11}$ inch diameter, was then mixed with the bond and water added until the mixture took the impress of the fingers when squeezed in the hand. The paste was then placed in a wooden mould, and compression applied through a flat piece of wood by blows from a hammer. The briquettes were afterwards dried in the sun. The defects in this method of manufacture are :—

(1) The paste was not steam-heated.

(2) The compression applied was quite insufficient—a pressure of about 2 tons per square inch being required.

The dimensions of the briquettes were 3" × 3" × 4". Their resistance to an endways compressive strain was determined in the testing machine at the Sibpur Engineering College,* and as a result of these experiments, I am of the opinion that satisfactory briquettes can be made from Ladda coal. Before importing briquetting plant, however, about 5 tons should be shipped to some makers of briquetting machinery for an opinion as to the most suitable bond.

In the following table, details of the briquetting experiments are given :—

Details of briquetting experiments.

Serial number.	COMPOSITION		Pressure, in lbs. per square inch, under which a briquette broke when placed on end in the testing machine.	Result of burning trial, and remarks.
	Coal.	Bond.		
1	100 parts.	2 parts of lime	Soft	B.
2	100 parts.	3 parts of lime .	"	
3	100 parts.	4 parts of lime .	"	

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* I have pleasure in expressing my obligation to the College authorities and particularly to Mr. W. H. Everitt, the Professor in Engineering, for kindly assistance in carrying out the tests.

Details of the briquetting experiments —continued.

Serial number.	Composition.		Pressure, in lbs. per square inch, under which a briquette broke when placed on end in the testing machine.	Result of burning trial, and remarks.
	Coal.	Bond.		
4	100 parts.	3 parts of lime . 1 part of "mah" meal.	82	Burnt freely with small amount of yellow flame. Cracked in furnace but did not break up.
5	100 parts.	2 parts of lime . 2 parts of "mah" meal.	97	
6	100 parts.	1 part of lime . 3 parts of "mah" meal	162	
7	100 parts.	5 parts of pounded mustard seed.	87	
8	100 parts.	5 parts of oil cake made from mustard seed.	117	
9	100 parts.	5 parts of wheat flour.	226	
10	100 parts	7½ parts of liquid tar	11	This poor result is to be accounted for by the fact of the mixtures not being steam heated before manufacture.
11	100 parts.	10 parts of liquid tar.	15	
12	100 parts.	2 parts of liquid tar. 3 parts of oil cake.	9	
13	100 parts.	2 parts of liquid tar. 3 parts of wheat flour.	28	
14	97 parts.	3 parts of lime .	97	
15	94 parts.	6 parts of pitch.	244	Machine-made in the North-Western Railway Co's. factory at Haranpur.
16	92 parts of Dandót coal dust	8 parts of pitch.	163	
17	90(?) parts of Welsh coal dust	10(?) parts of pitch.	1,653	Specially made for storage purposes on the North-Western Railway.

Washing.

The quality of the coal might easily and cheaply be improved by subjecting it to a washing process. With the object of ascertaining if this could be successfully done I made experiments in a roughly-constructed washer on the trough principle. This machine consisted of a wooden trough, 24 feet in length, 8 inches deep, and 8 inches wide. At intervals of about 5 feet wooden "riffles" or partitions, 5 inches in height, were fixed in the trough. It was placed in position with a slope of about 1 in 15. A stream of coal and water was then led into the upper end of the trough, and passed through it, rising successively over each riffle. At the same time the coal was raked backwards towards the upper end of the trough By this means a concentration of the heavy dirt took place behind the riffles, whilst the lighter coal passed on out of the trough and was collected over a fine-meshed screen. The coal experimented with contained 39·6 per cent. of dirt, and this was reduced by the washing to 24 per cent

It may be remarked that, depending as it does upon the difference in the specific gravity of the lumps of coal and dirt, coal washing can only be successful when the coal is separated by a screening operation into lumps of equal size, of which each size is washed separately.

In the above-described experiments unsized coal was used and consequently the result achieved—a reduction of the amount of dirt by 40 per cent.—is by no means an unimportant one. I am, therefore, of the opinion that, with careful sizing, Ladda coal might be satisfactorily washed in trough washers on a large scale. The trough washer is the cheapest in first cost, and simplest of the numerous types of coal-washing machines.

Coking.

Whilst in the field I made a number of coking experiments * with Ladda coal from E drive. The oven used was roughly constructed of

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* I have pleasure in expressing my thanks to Mr. J. Godwin, the officer in charge of the coal prospecting operations, for his valuable assistance in carrying out the washing, briquetting, and coking experiments.

undressed stone, plastered with mud. The waste gases were passed through a straight, iron pipe, 32 feet long, cooled externally by running water. The coking occupied about three days. Owing to my not having time to personally superintend the varying admission of the air-supply to the oven, the fire became extinguished before the coking was complete. Two experiments were made, the resulting product, in both cases, being large lumps of fairly hard, three parts coked coal. The condensation products were chiefly water obtained from the evaporation and subsequent condensation of the water contained in the mud used in plastering the oven-walls. On the top of the water floated a skim of light oil. No tar or heavy oils were obtained.

In a third experiment, coal dust was placed in a galvanized iron pipe, pierced with small holes, which was heated in a furnace. In still another experiment, a drum of wrought steel, a sixteenth of an inch thick, was substituted for the pipe. The coke obtained from both experiments was hard, dense, and grey in colour. Some pieces, however, were bright and silvery.

The conclusion that may be drawn from these experiments is, that a serviceable foundry coke can be made from Ladda (E drive) coal. Greater heat, however, is required in the coking than is necessary in the case of most coking coals. As a consequence, flue ovens, as opposed to those of the bee-hive type, would be necessary.

X.

THE WORKABLE AREAS AND THE QUANTITY OF FUEL AVAILABLE.

When in the field together, Messrs. Oldham, Hope, and the Writer arrived at the conclusion that the existence of a continuous seam of coal in the Ladda coal-field, between Jungle gully and Hákroli (in the Anji valley), was fairly well proved. At the same time, owing to the great variability in the thickness of the coal seam, we did not think that sufficient evidence had been obtained to enable an authoritative opinion as to its workability to be given. In order to decide this point we agreed that a number of drives, not less than 500 feet in length, should be driven in from certain selected points on the outcrop of the seam.

Results of the long drives in the Ladda field.

On my second visit to the Ladda coal-field, I had an opportunity of visiting these drives and making the observations necessary for the forming of an opinion. These observations are summarized in the following table :—

Locality and name of tunnel.	Distances between which measured sections at 5 feet intervals were taken	Average thickness of coal.	Remarks.
Jungle gully, Drive A	from 90 to 320	1 11	
Ditto .	from 320 to 435′	2 3	
Jungle gully, Drive E	from 70′ to 550′	3′ 0′	
Jungle gully, Drive F.	from 0 to 32	8′ 0	
Ditto . .	from 32′ to 145′	0 0″	
Ditto . .	from 145 to 302′	0 9	
Santráni kund, in the Anji valley.	from 86′ to 350′	3′ 0″	Coal too impure to be workable.
Nadla, in the Anji valley	from 93′ to 295′	4 9′	Coal is in bands with shale between.
All drives . .	1,329 feet of driving	2 7	Neglecting the figures for the Santráni kund drive.

From which it can be seen that for 1,329 feet of driving on the coal seam the average thickness of coal was 2 feet 7 inches; a thickness which may, perhaps, under the circumstances, be considered just workable.

Although every effort was made to preserve the original direction of the drives, yet, on account of the variable strike, they are most tortuous, right angle bends being frequent. For this reason great difficulty was experienced in fixing the ventilating pipes and in getting out the coal from the working-face to the surface.

Division of the coal areas.

It will be convenient, for the purpose of estimating the quantity of fuel available, to divide the coal-fields into the following areas:—

A.—The Ladda and Sangar Marg coal-fields.

- (1) The area from which coal might be brought to a railway with terminus at the foot of the Ladda slope.
  - (*a*) The country south of Sandráni and Mootal.
  - (*b*) The Ladda slope.
  - (*c*) The Sukhál gully southern slope.
- (2) The area from which coal might be brought to a railway aligned along the Anji valley.
  - (*a*) The slope from Sukhál gully to the Anji stream.
  - (*b*) The northern slope of the Anji valley.
- (3) The ground between the Anji valley and Sangar Marg.
- (4) The Sangar Marg (Ikni Krool) area.
  - (*a*) The Ikni-Sujánpur slope.
  - (*b*) The Sujánpur synclinal.
  - (*c*) The Bugoola synclinal.

B.—The Mehowgala field.

C.—The Siró valley field.

D.—The Kálakót field.

E.—The Lodhra field.

Considering these areas in the above order :—

A.—THE LADDA AND SANGAR MARG FIELDS.

(*1*) *The areas from which coal might be brought to a railway with terminus at the foot of the Ladda slope.*

(*a*) *The country south of Sandráni and Mootal.*—Excavations on a line between Sandráni and Mootal have failed to prove the existence of a workable coal seam. To the south a steady succession of the beds overlying the coal measures, dipping from north-east to south-west at angles of from 25° to 45°, is seen for several miles. It is possible that folding has repeated these outcrops, and that at certain points the *coal measures* may have been brought up within a reasonable distance from the surface. This could only be ascertained by boring operations.

The only advantages which would attach to the working of coal in this area would be its closer proximity to markets, and the avoidance of the inclines or ropeways which will be required for bringing down the coal from the mines in the hills. It does not appear likely that the coal will be found in any better physical condition than in the hill areas, and the slightly lower angle of dip would certainly render its working no more simple.

The disadvantages are apparent. The whole of the working would be to the dip, necessitating a heavy capital expenditure on deep shafts and pumping plant. The output obtainable from any pair of shafts would, owing to the comparatively high dip of the seam, be small. Under these circumstances I consider that it would be distinctly inadvisable to incur any expense in the search for coal in this locality.

(*b*) *The Ladda slope.*—Between Mootal and trial trench No. I, the *coal measures* are so much disturbed that the coal could not be profitably exploited. From the latter point to Karáta mill, a horizontal distance of about 2½ miles, the existence of a probably workable seam of coal, averaging 2 feet 2 inches in thickness,[1] has been fairly well proved.

The height from trial trench No. I to Gully pass is 1,643 feet, and the fall from the latter point to Karáta mill is 559 feet. The average dip of the seam is 45°. Allowing for a loss in working of 30 per cent., the amount of coal which might be extracted from above free drainage level is, therefore[2] :—

$$\left(\frac{12{,}148 \times 1{,}643 \times 13 \times 1.414}{2 \times 25 \times 6} - \frac{2{,}552 \times 559 \times 13 \times 1.414}{2 \times 25 \times 6}\right) \times \frac{7}{10}$$

$$= 795{,}029 \text{ tons.}$$

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[1] Calculated from table on page 245.

[2] This calculation and those following involve the following factors—

$$\frac{A \times B \times C \times D \times E}{F}$$

Where—

A = Horizontal distance in feet.
B = Vertical " "
C = Thickness of seam "
D = Co-secant of the angle of dip.
E = Fraction workable.
F = 25=Number of cubic feet in one ton of coal.

(*c*) *Sukhál gully, southern slope.*—No prospecting work has been done in this area. A drive near the bottom of the slope is said to have proved coal exceeding 16 feet in thickness. At the top of the slope an outcrop of coal 2 feet 6 inches thick is seen, but it is doubtful if this is the true coal-seam. Presuming, however, that the seam underlies this area and is workable, then the quantity of coal above free drainage level, assuming an average thickness of 2 feet 7 inches, and a working loss of 30 per cent., would be:—

$$\frac{6{,}600 \times 2\,460 \times 13 \times 1{\cdot}414 \times 7}{2 \times 25 \times 10 \times 6} = 696{,}383 \text{ tons}$$

This estimate includes only the coal lying above the level of Karáta mill, at the foot of the slope. Should it be found possible to drive roads through from the lowest workable point on the Ladda slope to work the deeper-lying coal on the Sukhál slope, then the above estimate would have to be increased by 613,730 tons.

(2) *The area from which coal might be brought to a railway aligned along the Anji valley.*

(*a*) *The slope from Sukhál gully to the Anji stream.*—The quality of the coal obtained from the long drive at Santráni kund is so disappointing (two samples yielded, respectively, 42 and 62 per cent. of ash, although an outcrop sample gave 34 per cent.) that I do not think this area should be reckoned upon.

(*b*) *The northern slope of the Anji valley.*—Over this ground the amount of ash in the samples taken varied from 6·72 to 61·44 per cent. As far as quality goes, parts of this area may be considered workable. In regard to the conditon of the seam the evidence is not so satisfactory. Faulting and frequent contortion of the rocks have taken place. On this account it will be prudent to count upon an extraction of only 50 per cent. of the seam. The distance along the Anji valley, horizontally, is about three miles. The average thickness of the seam may be taken as not less than 4 feet, with an average dip of 40°. The average height above the stream-bed is probably about 500 feet. On these assumptions the amount of workable fuel above free drainage level will be:—

$$\frac{15{,}840 \times 500 \times 4 \times 1\,5 \times 5}{25 \times 10} \quad 950{,}400 \text{ tons.}$$

Between the Anji stream and Punchári gully, no coal is exposed at the surface. A single drive near the stream-bed proved coal, exceeding 6 feet in thickness, which, on analysis, yielded 32 per cent. of ash. It is possible that the seam may continue of workable thickness and quality as far as Punchári gully. The horizontal distance is about 7,000 feet and the maximum height 1,700 feet. The seam has an average dip of 45°, and may prudently be presumed to be only 3 feet in thickness. Allowing for a working loss of 30 per cent the amount of coal available above free drainage level will be —

$$\frac{7{,}000 \times 1{,}700 \times 3 \times 1.414 \times 7}{2 \times 25 \times 10} = 706{,}717 \text{ tons}$$

(3) *The ground between the Anji valley and Sangar marg.*

With two exceptions the analyses of the samples from this area are uniformly bad, the ash varying from 52 to 80 per cent. The exceptions referred to are the analyses of the samples from the cutting at Cherungha in the Radd nala, about 1¼ miles west of Arnás, which yielded from 24 to 34 per cent of ash I do not think, however, that the exceptional result from this drive is important, for apart from the question of quality, the seam appears to be too inconstant in thickness to be workable. I have little hesitation, therefore, in condemning the whole area.

(4) *The Sangar Marg (Ikni-Krool) area.*

(*a*) *The Ikni-Sujánpur slope.*—The only exposures of coal are near Ikni at the summit of the hill. Assay results are conflicting: coal from a tunnel gave 13 per cent. ash in a sample from a point where the seam was 6½ feet thick, whilst samples from an outcrop 13 feet thick yielded, respectively, 55 and 62 per cent. of ash.

Between Ikni and Sujánpur the possible occurrence of a fault throwing down a portion of the *coal measures* is mentioned by Mr. La Touche (*Records, G. S. I.*, vol. XXI, part 2, p. 66), but I was unable to find any positive evidence of such, and taking into consideration the thinness and frequent absence of the coal seam in the Sujánpur syncline, I think it must be concluded that the seam is absent over this ground. This area, therefore, may be considered unworkable.

(*b*) *The Sujánpur Synclinal.*—Over this ground the seam, except in one place, is too thin to be workable. The exception occurs at a point near Chakka where the coal is nearly 3 feet thick, and yields only 7 per cent. of ash. On either side, however, the coal thins in a short distance to 15 inches.

In the small outlier on the crest of Sangar Marg hill at Sarodabár, the quality of the coal is too poor, the quantity too small, and the locality too difficult of access for the deposits to have any economic value. On general grounds, therefore, this area must be condemned as a coal producer.

(*c*) *The Bugoola Synclinal.*—From Brehal as far as Kálamitti the quality and thickness of the coal is too variable to afford any hope of its being profitably mined. On the southern side of the syncline a considerable thickness of coal is exposed in several places, but it is found that wherever the seam exceeds about 2 feet the quality of the coal is inferior. I have little hope, therefore, that mining in this area would prove to be commercially successful.

B.—THE MEHOWGALA FIELD.

In this field the quality of the coal is undoubtedly good. The thickness of the seam is, however, extremely variable. The height of the outcrop maintains a fairly general level, and practically no coal is available above free drainage level. In order to work the coal deep shafts and probably heavy pumping would be necessary. Under these circumstances I am distinctly of the opinion that mining on an extensive scale would not be profitable.

C.—THE SIRÓ VALLEY FIELD.

This field is the most promising of those on the west of the Chenáb. The quality of the coal appears to be, on the whole, fairly good. Its thickness, as elsewhere, is variable, but may be considered, as a rule, workable, seeing that the low dip of the beds to the south would allow of free drainage. I do not consider that any reliable estimate of the quantity available can be given, but taking the length of the roughly semi-circular outcrop as one mile, and presumng that the thickness of the coal averages 2 feet, and that a 70 per cent. extraction might be made, the amount available, within half a mile of the outcrop, would be rather more than three-quarters of a million tons.

The distance of the field from the railway terminus at Jammu (40 miles direct, over very difficult country) renders it extremely doubtful whether the profit from the working of the coal would ever repay the capital expended upon the construction of a railway line.

D.—THE KÁLAKÓT FIELD.

Although the quality of the coal in this field is marketable, yet its variability in thickness, the disturbed condition of the rocks, the necessity for deep shafts and pumping, together with the difficulty of access, render it impossible to look upon the exploitation of this field as a commercial venture with any prospect of success.

E.—THE LODHRA COAL-FIELD.

The analyses of the samples of coal from this locality vary in amount of ash from 59 to 78 per cent., exclusive of a sample (No. 89), from a band of coal 1 foot 6 inches thick, giving 32·2 per cent. of ash, and of a sample (No. 90), from a denuded outcrop 8 inches thick, showing 40·28 per cent. ash. In the face of these facts I am unable to recommend that any capital should be expended in opening up this field.

Summary of estimates.

Summarizing :—

The amount of coal which might be brought to a railway aligned to the foot of the Ladda slope is seen to be :—

	Tons.
Probable yield (from A, (1), b)	795,029
Possible yield (from A, (1), c)	696,383
Possible yield (from A, (1), c)	613,730
	2,105,142

The amount of coal which might be brought to a railway aligned along the Anji valley is :—

	Tons.
Probable yield (from A, (2), b)	950,400
Possible yield (from A, (2), b)	706,717
	1,657,117

These estimates include only the coal which might be worked from above free drainage level. Should it pay to establish pumping and hauling plant, they would be considerably increased.

XI.

ECONOMIC ASPECTS OF THE COAL QUESTION.

Market value of Ladda coal.

Before entering upon the consideration of the above subject it will be necessary to consider what the selling value of the coal will be. I am of the opinion that washed and briquetted Ladda coal will have an equal, if not a greater, value than Bengal coal.

Now at Wazirabád Station, the junction of the Tawi branch of the North Western Railway with the main line, Bengal and Ladda coal would enter into competition on equal terms for all places north and west of that place. From data which have been supplied by the officials of the North Western Railway Company, I have calculated that the average cost of Bengal coal delivered at Wazirabad is Rs. 19-11-8 per ton. In the following calculations, therefore, I propose to estimate the probable cost per ton of landing Ladda coal at Wazirabád and, to consider the difference between this sum and the amount Rs. 19-11-8 as profit or loss.

As has been already shown, there are two areas in which coal possibly workable at a profit occurs. These areas are—

(1) The Ladda slope, approached through Tikri and Mootal.

(2) The Anji valley, approached through Riássi and the valley of the Anji stream.

Most favourable position for a colliery.

For both of these areas the final outlet to existing markets must be through the North Western Railway Company's line connecting Jammu (Tawi) with the Company's main line at Wazirabad. Should it be decided to commence the working of coal in only one of these areas, undoubtedly the Ladda slope should be chosen, because the cost of transport to Tawi from the Anji valley area would exceed the cost of transport from the Ladda area to the same place by more than 40 per cent. The alignment of the Jammu-Kashmir line would, however, affect this question.

Probable output of coal.

Presuming, then, that a colliery is to be established on the Ladda slope, the first point to be decided would be the probable output which may be counted upon. Mr. Hope estimated this at 400 tons a day; which for 300 working days would be 120,000 tons per annum This amount is probably somewhat in excess of the amount which a 2′ 6″ gauge railway could carry, presuming that 12 trains, with an average load of 27 tons (Mr. Weightman's estimate[1]), could be run daily. Taking into consideration this fact and the fact that there would probably be difficulty in obtaining suitable mining labour, I am inclined to consider Mr. Hope's estimate somewhat high. I propose, therefore, to base my estimates on a presumed output of 50,000 tons per annum.

A.—Estimates for the Ladda Slope.

	Rs.
Cost of 2′ 6″ gauge railway from Mootal to Tawi (Mr Weightman's estimate)	31,00,000
Interest and depreciation on 31 lakhs at 11 per cent.	3,05,000
Working expenses on the carriage of 50,000 tons of coal at the rate of ⅛ pie per maund per mile (Mr. Weightman's rate)	58,333
	3,63,333
Deduct—Earnings on account of ordinary local traffic (Mr. Weightman's estimate) . . .	56,039
	3,07,294

Cost per ton for transport of 50,000 tons of coal to Tawi . . . . . $= \frac{3,07,294}{50,000} =$ Rs 6-2-4

The actual cost per ton for washing coal in a number of European plants has been calculated to be as follows :—

		Cost per ton, in pence.
Lührig washer	. . . . . .	1·08 0·79
Murton washer	modified trough types . .	0·76
Elliott „		0·88
Trough washer	. . . . . .	3·00

The greater cost of coal-washing in a trough machine is due to the large amount of labour required. With cheap Indian labour, trough-washing would probably be as cheap in working cost as any other system, and there is the additional advantage that the capital cost is extremely low. No expensive machinery need be imported from Europe, as would be necessary in the case of the more elaborate systems of washing. The whole of the construction would not be beyond the powers of native carpentry.

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[1] Report on the Kashmir Railway.

The cost per ton of making Dandot coal briquettes in a plant at Haranpur, for an output of 20 tons, has been estimated to be Rs. 6-0-0.

The average cost per ton in a number of European plants briquetting 100 tons per day has been calculated to be Rs. 2-7-0.

This latter figure would be increased by the enhanced price of pitch in India to Rs. 2-14-0.

With a plant briquetting about 250 tons per day, the economy would be much greater than in a small plant such as that at Haranpur or even in the case of the 100-ton European plants.

Allowing a margin of one-third over the European cost for the increased expense of operating a plant in India, the cost per ton of washing the coal and manufacturing it into briquettes with pitch should not exceed Rs. 4-0-0 (2).

The cost of mining coal under somewhat similar conditions at Dandot Colliery is said to be Rs. 6 per ton. Owing to the softer nature of the Ladda coal, probably the actual getting cost would be less than at Dandot, but on the other hand the cost for dead work would be much greater owing to the more disturbed condition of the seam. Taking these facts into consideration, I am inclined to think the mining cost per ton would not be less than Rs. 9-0-0 (1).

A reduction by 20 per cent. due to the removal of the dirt would add to the mining cost per ton by Rs. 2-4-0 (3).

ESTIMATE NO. I.

For an output of 50,000 tons per annum.
(Ladda slope.)

	Cost per ton. Rs.	a.	p.
Mining (1)	9	0	0
Washing and briquetting (2)	4	0	0
Loss by reduction of dirt in coal (3)	2	4	0
Interest and depreciation at 11 per cent. on capital required for the development of the colliery, say, 4 lakhs	0	6	4
Management and offices	0	6	0
Transport to Tawi (4)	6	2	4
Transport from Tawi to Wazirabad	0	11	0
	22	13	8
Selling price at Wazirabad	19	11	8
Loss per ton	3	2	0

A loss of Rs. 3-2-0 per ton would give an annual loss of Rs. 1,68,750, which, on a capital of 35 lakhs, would amount to 4·8 per cent.

From a knowledge of the present state of the investigation for the alignment of the proposed Jammu-Kashmir Railway, there appears to be little chance of the route followed passing within reasonable distance of the Ladda slope, and consequently no relief in transport rates can be hoped for from the building of that railway.

Bullock traction

It has been proposed, however, to work the coal-line between Mootal, at the foot of the Ladda slope, and Tawi by means of bullock traction, and to utilize the existing cart-road between Tawi and Udhampur. The representatives of a well-known engineering firm have visited the neighbourhood and reported most favourably upon such a project. Their estimate for supplying the rails, wagons, etc., necessary for a line designed to carry 500 tons of coal per day, amounts to nearly 4½ lakhs. Using this estimate, the cost of a line worked by bullock traction and designed to carry a maximum of 250 tons per day would be approximately:—

	Rs.
Formation between the cart-road at Tikri and Mootal, 10 miles at, say, Rs. 40,000 per mile	4,00,000
Rails, wagons, plant, etc., for 50 miles .	3,00,000
Sleepers, 2,000 per mile, at As. 12 each .	75,000
Laying rails, at Rs. 500 per mile . . .	25,000
Ballasting, at Rs. 500 per mile . . .	25,000
800 bullocks, at Rs. 30 each . . .	24,000
Total cost of line	= 8,49,000
	or say, 8½ lakhs.

	Rs.
Interest and depreciation on 8½ lakhs, at 11 per cent.	93,500
Carriage of 50,000 tons of coal, at ¼ pie per maund per mile	58,333
Earnings on account of ordinary local traffic	56,039
	2,07,872
	say, 2 lakhs.

Cost per ton for transport of 50,000 tons of coal from Mootal to Tawi . . $= \frac{2,000,000}{50,000} =$ Rs. 4.

ESTIMATE NO. II (LADDA SLOPE).

Substituting this amount Rs. 4 for the transport cost in estimate No. I, the loss per ton is reduced from Rs. 3-2 0 to rather less than Re. 1. This, on a capital of 12½ lakhs, would give an annual loss of 4 per cent.

B.—Estimates for the Anji valley area.

Following the proposed alignment for the Chenáb valley route from Jammu to Srinagar, the Anji valley is reached, at a distance of 42½ miles from Tawi, at a point about one mile west of the nearest coal outcrop in the Anji valley. From this point the colliery line would follow up the nala, for about two miles, to a point well within the coal area. Using Mr. Weightman's estimated construction rates per mile, the cost of this line would be:—

	Rs.
30 miles at Rs. 80,000 per mile	=24,00,000
10 " " " 1,00,000 " "	=10,00,000
2½ " " " 1,50,000 " " . . .	= 3,75,000
2 " " " 2,00,000 " "	= 4,00,000
	41,75,000

The total capital expenditure on this line would therefore be, say, 42 lakhs. Using methods of calculation similar to those employed in the Ladda estimate, and allowing for a profit on ordinary local traffic of Rs. 30,000 (Mr. Weightman's estimate), the cost per ton for the transport of 50,000 tons from the Anji valley coal-field to Tawi would be Rs. 9-15-0.

ESTIMATE NO. III.

For an output of 50,000 tons per annum (Anji valley field).

Substituting the amount Rs. 9-15-0 for the transport cost per ton in Estimate No. I, the loss per ton is seen to be nearly Rs. 7. This would yield a loss of Rs. 3,50,000, which, on a capital of 46 lakhs, would give an annual loss of 7·6 per cent.

The proposed Anji valley branch of the Jammu-Kashmir railway.

The latest alignment for the Jammu–Kashmir railway passes through Talwára, a village situated on the right bank of the Chenáb River, and some two miles to the west of Piássi. Should this route be finally decided upon, it might be practicable to build a branch line connecting the Anji valley coal-field with the main line at Talwára. On the map the direct distance between Talwára and the terminus of the branch line is 10 miles, but the total length of line necessary would probably not be less than 13 miles. Besides an expensive crossing of the Chenáb, the construction cost of a line following the Anji nala would be very heavy, not less than 2 lakhs per mile, judging from Mr Weightman's figures for similar constructions. Should such a line be practicable it would, however, considerably lower the cost of transport of coal between the Anji valley and Tawi.

		Rs.
13 miles, at Rs. 200,000 per mile	=	26,00,000
Interest and depreciation on 26 lakhs, at 11 per cent	=	2,80,000
Carriage of 50,000 tons of coal for 55 miles, at ⅕ pie per maund per mile	=	77,344
	=	3,63,344
Cost per ton for the transport of 50,000 tons of coal from the Anji valey to Jammu . . $= \frac{3,63,344}{50,000}$	=	Rs.7-4-3

ESTIMATE NO. IV (ANJI VALLEY FIELD.)

Substituting this amount Rs.7-4-3 for the transport cost in Estimate No. III, the loss per ton is reduced from Rs.7 (nearly) to Rs.4-4. This, on a capital of 30 lakhs, would give an annual loss of 7·1 per cent.

SUMMARY OF ESTIMATES.

Locality.	Traction.	Estimated Capital.	Annual loss.
			per cent.
Ladda .	Steam	35 lakhs .	4·8
Ladda .	Bullock	12½ „ . .	4
Anji valley	Steam, independent line . .	40 „ . .	7·6
Anji valley	Steam, *viâ* Anji nala, and joining the Jammu-Kashmir proposed line at Talwára .	30 „ . .	7·1

It has been estimated by Mr. Weightman that for the working of the ordinary traffic (excluding coal traffic) on the Kashmir Railway, nearly 11,000 tons of coal per annum would be required. Even with the assistance which this local market would afford, the working of the Jammu coal-fields, under the present circumstances, cannot be considered a sound commercial proposition.

XII.

SUGGESTED METHODS OF WORKING.

There can be no doubt that the working of the Ladda coal will be difficult, and will call for the highest technical skill. The reasons for this are as follows:—

(1) The high inclination of the seam.
(2) The soft and broken character of the rocks.
(3) The possibility of landslips due to the disturbance of equilibrium set up by the extraction of the coal-seam.
(4) The variability in the quality and thickness of the coal-seam.
(5) The probably heavy water discharge.
(6) The presence of fire-damp.

Under these circumstances it would be advisable, before commencing serious work, to procure the services of a skilled European mining engineer, by whom the whole of the mining operations would be laid out. By this precaution, initial mistakes, which might have serious consequences in the future, would be avoided.

In his report on the Ladda coal-field, Mr. Hope gave a description of a proposed method of working the coal. Briefly, this method is as follows:—Taking a hill-slope upon which the coal-seam outcrops, sites for main winnings would be selected 500 feet apart vertically. Each winning would consist of a pair of tunnels, 60 feet apart, rising 1 in 120, and connected for ventilation by cross-drives 100 feet apart. When these tunnels have reached their limit, a pair of roads, 250 feet back from the face of the tunnels, would be driven up on the full slope of the seam to within 100 feet of the outcrop, or the next highest winning, as the case might be. From these rise-roads pillars would be opened out for a distance of 250 feet on either side; such pillars to be worked back in descending order. Whilst these are being worked back a new pair of rises would be put up 500 feet further back, ready for pillar working and extraction. By this means both coal and water would descend by gravity to the mouths of the main drifts.

The method of working, outlined above, is a distinctly practical and sound one. I am, however, inclined to think that it would not be advisable, from an economic point of view, to delay the working-out of each section (500 feet × limit) until the pair of roads commanding it has reached its furthest limit. In the case of the longer drives this limit might be as much as two miles, or even further. This means that at an average rate of three feet per working day, this pair of roads, for at least ten years, would produce not more than 3 tons per day, and the whole of this time the up-keep of a great length of roadway, together with the expense of a ventilating fan, would have to be provided for. It is certain that main roads driven in the coal would be very expensive, if not economically impossible to maintain. The coal itself, as has been mentioned above, is extremely friable, and pillars formed in the seam would undoubtedly speedily crumble at the edges and afford but slight support for the roads. At the same time, the roof and floor of soft shale would be another source of weakness. Taking into consideration these factors, I would recommend that the main haulage (intake) and return-air roads should be driven in the ironstone shales lying below the coal-seam. From these roads, at intervals of, say, 500 feet, pairs of cross-measure drifts would be driven, at a slight up-grade, into the coal-seam. These drifts would not be more than 50 feet in length, and from each pair an area of the coal-seam, measuring 500 feet on both strike and dip, might be entirely worked out, and the roof allowed to fall, without damaging the main roads lying securely below in the shales. At the same time the main roads would be steadily driven ahead and successive areas opened out in a similar manner. It would thus be unnecessary to leave barriers between adjacent winnings. The whole of the seam, except an outcrop barrier of 100 feet thickness, might be removed. In this way, each winning would become speedily productive, and the cost of driving the main roads and of up-keep generally, be defrayed from current revenue. The cost of driving these main tunnels should not exceed eight rupees per foot, and this, allowing for the expense of the driving of the ventilation-holings and the cross-measure drifts, would be a constant charge on the coal of about 7 annas per ton, presuming that the average thickness of the seam is 2½ feet.

In Europe highly inclined and contorted coal-seams are, as a rule, worked on the longwall system. In this method of working no coal pillars are formed and left for subsequent extraction, the whole of the coal being removed in a continuous face, at one working. The roads are maintained through the "waste" or "gob" by means of pack-walls built of stone obtained from the bands of stone in the coal-seam or from the ripping of the roof in the roads. In some cases stone for packing and filling the waste is taken down from the surface.

I am of the opinion that this method of working might be successfully adopted in the Ladda coal-field. The chief difficulties would lie in the varying thickness of the seam and the scarcity of packing material. The roads would undoubtedly be difficult to maintain in those places where the seam is thick. Both methods might easily be tried in different areas, and the most successful method adopted generally. It is probable that where the seam is thin, longwall working would be advantageous.

Ventilation and lighting.

The question of ventilation is a most important one, especially so considering that fire-damp is given off from the coal. It will be absolutely necessary to maintain throughout the workings a current of air sufficient—in the words of the English Coal Mines Act—to dilute and render harmless noxious gases to such an extent that the working places and travelling roads of the mine may be safe for persons working and travelling therein. To effect this, artificial, as opposed to natural, ventilation will be necessary. Each main winning will therefore require to be ventilated by means of a fan—preferably of the Capell or Schiele type—driven either by a steam engine, or by Pelton wheels, or turbines. Ample power to drive the latter could be obtained by damming one or more of the numerous mountain streams in the neighbourhood.

In regard to lighting, the presence of fire-damp will render imperative the use of safety lamps throughout the workings. In the hands of the natives some simple type of lamp, such as those of the Marsaut pattern, would probably give the best results.

APPENDIX.

NOTE BY MR. E. L. HOPE ON THE JAMMU COAL-FIELDS.

On this my second visit to the coal-fields I was associated with Messrs. Oldham and Simpson, of the Geological Survey of India, the idea being, I understand, that, having had previous experience in the working of highly inclined coal-seams in India, I should advise further as to the best method of working the coal.

2. I arrived at Jammu on the 23rd March 1903, and, meeting Mr. Simpson between Assan and Thalwal on the 28th idem, accompanied him along the coal outcrop as far as Bakl on the Chenab.

From there we returned to meet the Resident in Kashmir at Mootal on the 12th April, being also in company with Mr. Oldham during the latter part of the tour.

I then retraced my steps alone as far as Assan to fix sites for trial headings, eventually leaving the coal-field on the 18th April.

3. This further examination of the outcrop has confirmed the opinion expressed in my note, dated 9th December 1902, that a large area of coal exists, but as the further trials of the coal and the exploratory headings recommended in my first note have not yet been pushed on with, I have very little to add to the remarks *re* the value of the field and the opening out of workings made in paragraph 4 of the same.

4. It seems quite clear, however, from the behaviour of such drifts as have been driven, that if coal-working on a large scale is to be undertaken, it will be practically impossible to maintain the main roads of the mines in the coal-seam itself. Driving in some firmer strata at a distance from the coal and its soft shales, and cross-cutting over to the seam at intervals as required will be imperative.

The ferruginous shales about 20 to 50 feet below the seam should form a good medium in which to drive main intake and return air roads. The expense to be incurred in the first instance would, in my opinion, be more than recouped in the reduced cost of maintenance and the lighter timbering required.

In discussing this matter with Mr. Simpson he pointed out that if such roads were driven, they would, being below the coal, be practically uninfluenced by the subsidence of roof which would occur during the process of extraction of the coal itself, and this being so, such extraction could be taken in hand as soon as the circumstances of the seam admitted of it, instead of waiting until the main roads of any individual set of workings had reached their limit, and then working the coal back, as I had originally suggested.

With this view I quite agree: the advantages are so obvious as to need no discussion.

5. The exploratory headings referred to in paragraph 3 above should now be pushed on with.

Sites have been selected as follows :—

(*a*) At Hakroli, under the lands of Assan village ; the outcrop is visible in the bed of the Anji stream, but to ensure safety from floods, the site for the mouth has been fixed higher up the hillside where excavations to find the coal horizon are already in progress.

(*b*) At Satrani Kund, about half way (vertically) between Sukhal gully pass and the Anji stream. The direction of dip of the strata here is about N. 42° E., but the drift has been set off to go at N. 68° E., so as to keep it as far as possible in firm ground. Probably about 100 feet dead work may have to be driven before the coal horizon can be struck. When coal is found it should, of course, be followed along the strike of the measures.

(*c*) At Jungle, below the Jungle drive, at the point originally proposed in my first note.

This drift will also have to pass through some loose ground owing to a surface slip, but it is not expected that the latter will prove of any great extent.

Possibly in none of the above headings will any ventilation, other than what can be set up by means of rotary hand fans, be required. It is understood that Mr. Godwin will arrange for the necessary plant, whereby the cost of secondary headings will be saved.

6. In my first note I recommended short drifts to be put in about 1,000 feet apart on the hillside between the Anji stream and Sukhal gully. Excavations for these have been started, but the surface soil is so loose that it is doubtful whether they can be put in without considerable expense. I think, therefore, they might be abandoned for the present.

I also consider that, as the continuity of the seam over a fairly large area is more or less proved, no more minor explorations are required at present, with the exception of a small drift at Nadla, near Assan, and the excavations to find the coal horizon about 500 feet above the Anji stream at Thalwal, at both of which places it would be advantageous to prove the existence of the coal, could this be done without much expenditure.

Drift "Baoli No. 3," which has just struck good coal, might also go on a few feet further.

What is urgently required now is to test the behaviour of the seam, *i.e.*, to ascertain to what extent it thickens and thins, and whether this irregularity will militate against its successful working. Valuable information in this respect should be obtainable from the three main exploratory headings at Hakroli, Satrani Kund, and Jungle, of which carefully recorded sections should be maintained.

G. I. C. P. No. 323 D. G. Survey.—24-8-04.—J. Marum.

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OF

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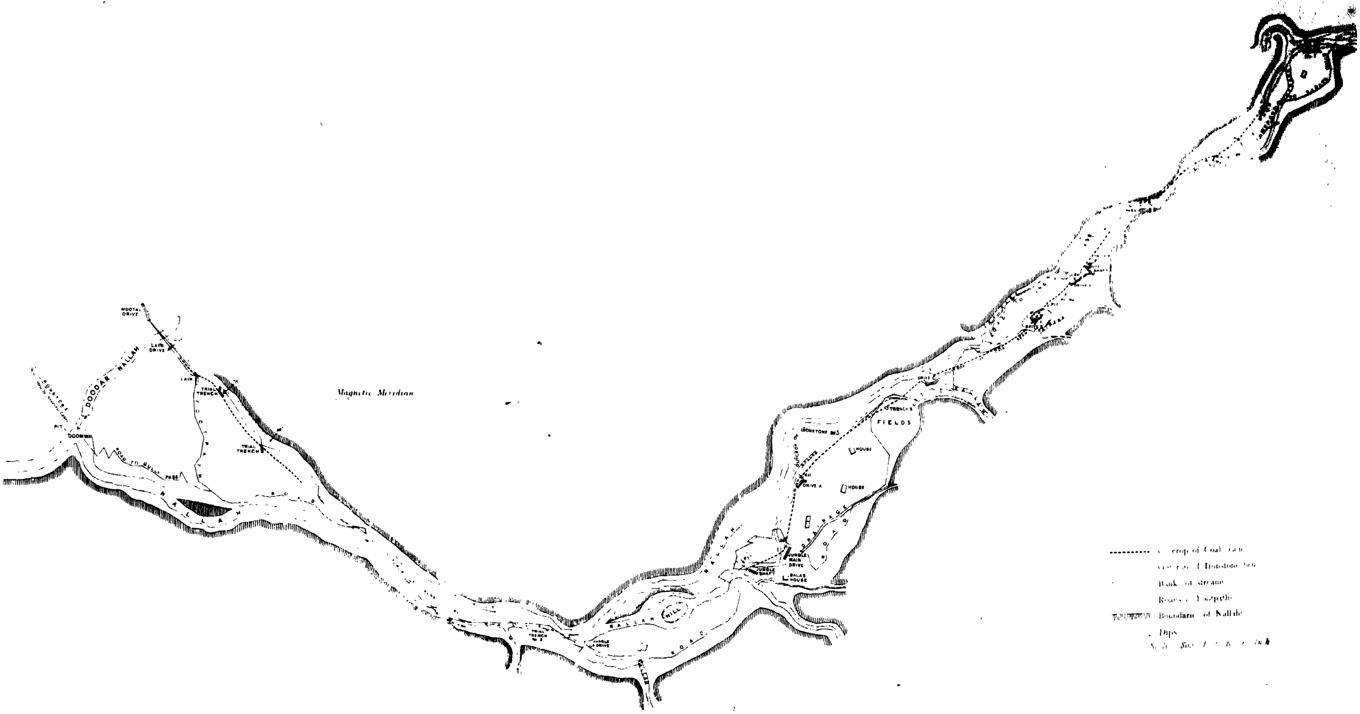
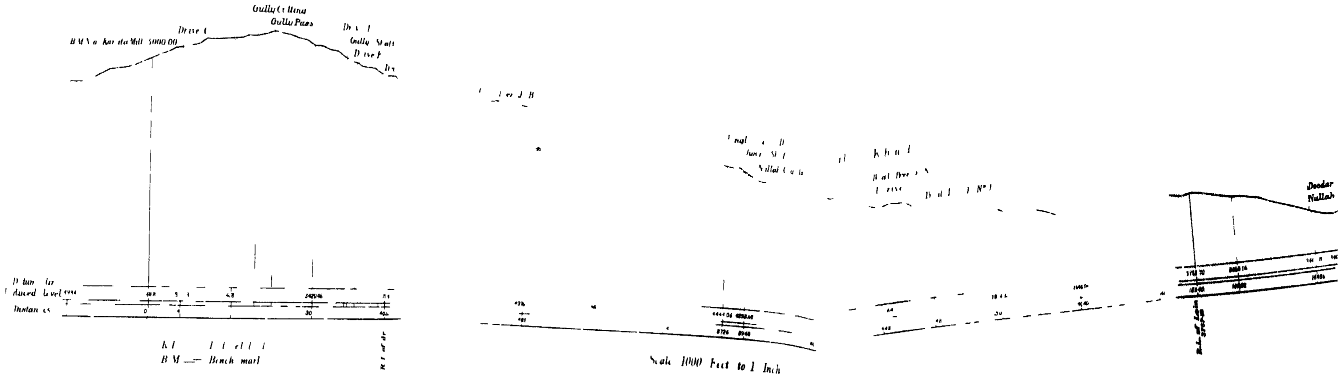


SURVEY PLAN OF PROSPECTS IN JUNGLE GULLY, LADDA COALFIELD.

(Longitude 75° 6′—Latitude 33° 0′)



LONGITUDINAL SECTION OF JUNGLE GULLY, LADDA COALFIELD.

Showing reduced level of Shafts, Drives Trench and Adits

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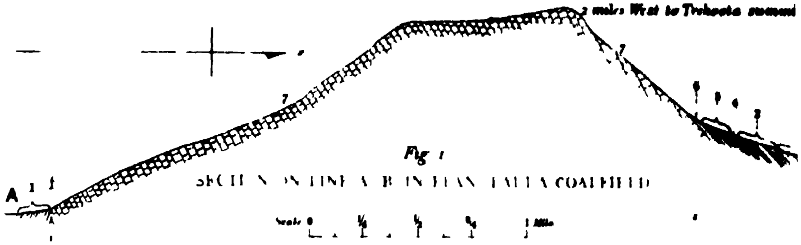


Fig 1

SECTION ON LINE A B IN PLAN LADDA COALFIELD

1 Grey Sandstones & red clays (Murree)
2 Olive Shales with nummulitic limestone } (Subathu)
3 Coal Seam
4 Ironstone shales
5 Shales
6 Siliceous grit
7 Great Limestone
f Fault

SECTION ON LINE C D IN PLAN LADDA COALFIELD

Showing reversed fault in Doodar gorge

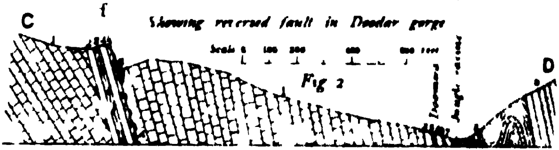


Fig 2

6 Coal Seam with coaly shales
5 Shales
4 Ironstone
3 Ironstone shales
2 Ironstone
1 Great Limestone
f Faults
A Main Drive

9 Grey sandstones & red clays
8 Olive shales & nummulitic limestone
7 Limestone debris
5 Grey black clay with coal pipes & limestone bands
4 Ironstone
3 Ironstone shales
2 Ironstone
1 Great Limestone

SECTION ON LINE E F IN PLAN LODHRA COALFIELD, JAMMU

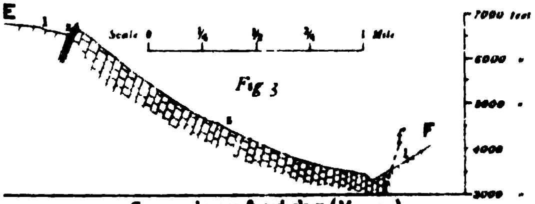


Fig 3

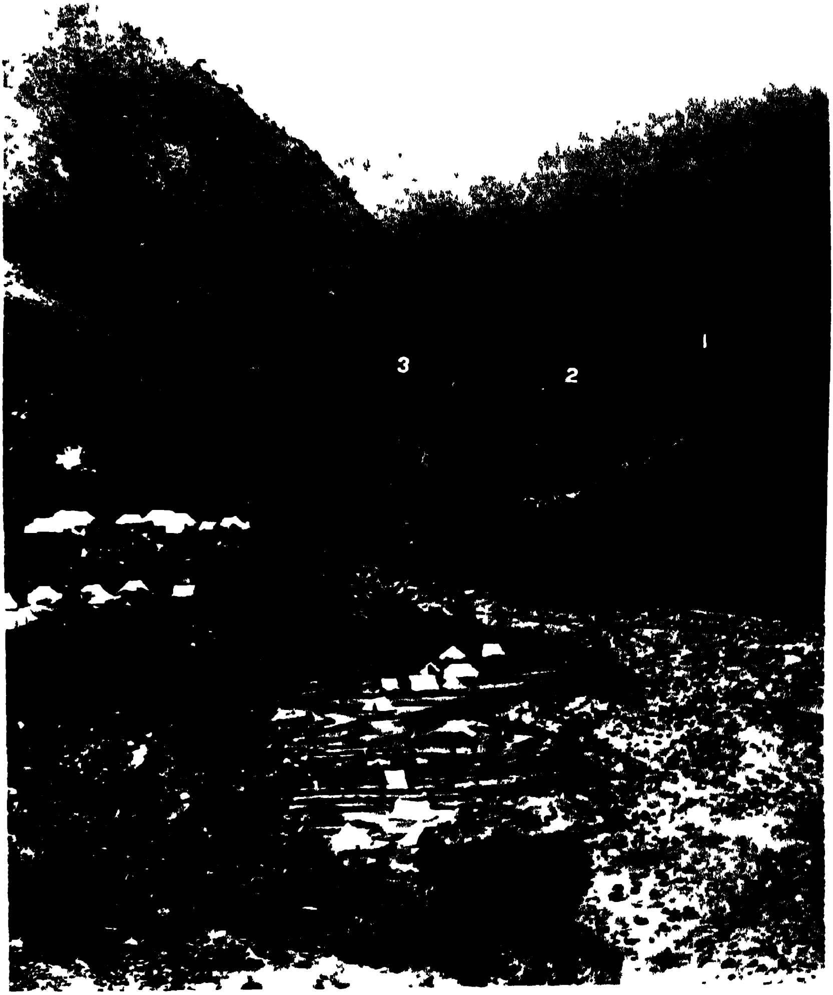
1 Grey sandstones & red clays (Murree)
2 Olive shales & nummulitic limestone } (Subathu)
3 Coal
4 Ironstone shales
5 Great Limestone (Pre-tertiary)
f Fault

SECTIONS OF THE LADDA AND LODHRA COALFIELDS.

PLATE 5.

PHOTOGRAPHED BY R. D. OLDHAM.

1. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
3. Blue-grey limestone (pre-Tertiary).

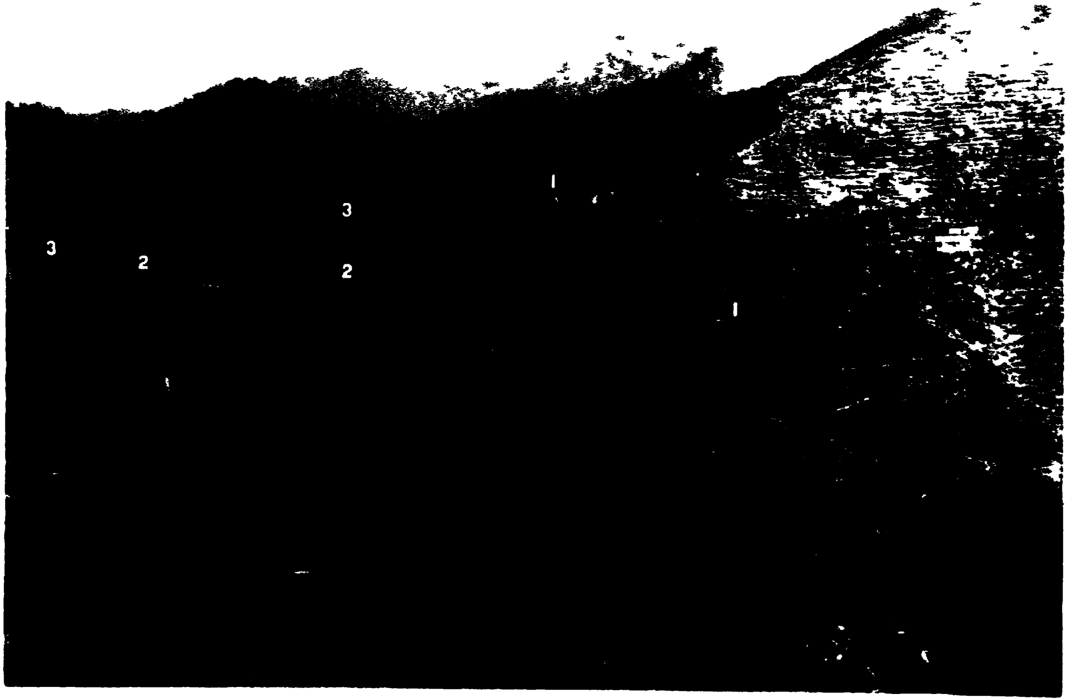


JUNGLE RAVINE LADDA COALFIELD JAMMU

PLATE 6.

PHOTOGRAPHED BY R. D. OLDHAM.

3. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
1. Blue-grey limestone (pre-Tertiary).



ANJI VA EY ADDA COALFIELD JAMMU

PLATE 7.

1 Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
3. Blue-grey limestone (pre-Tertiary)

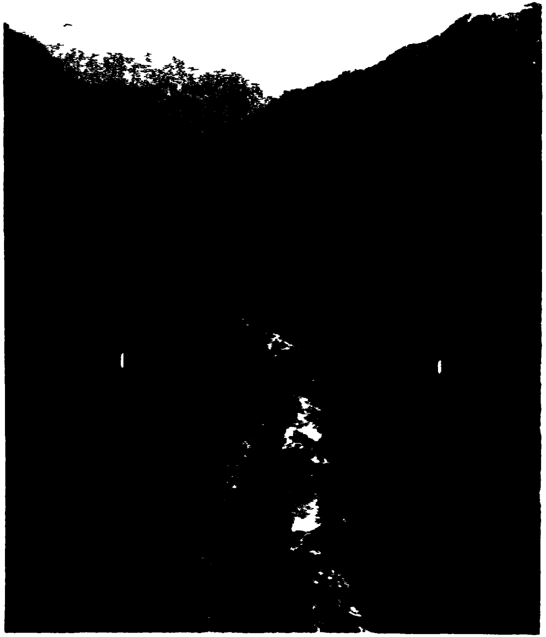


Fig. 1

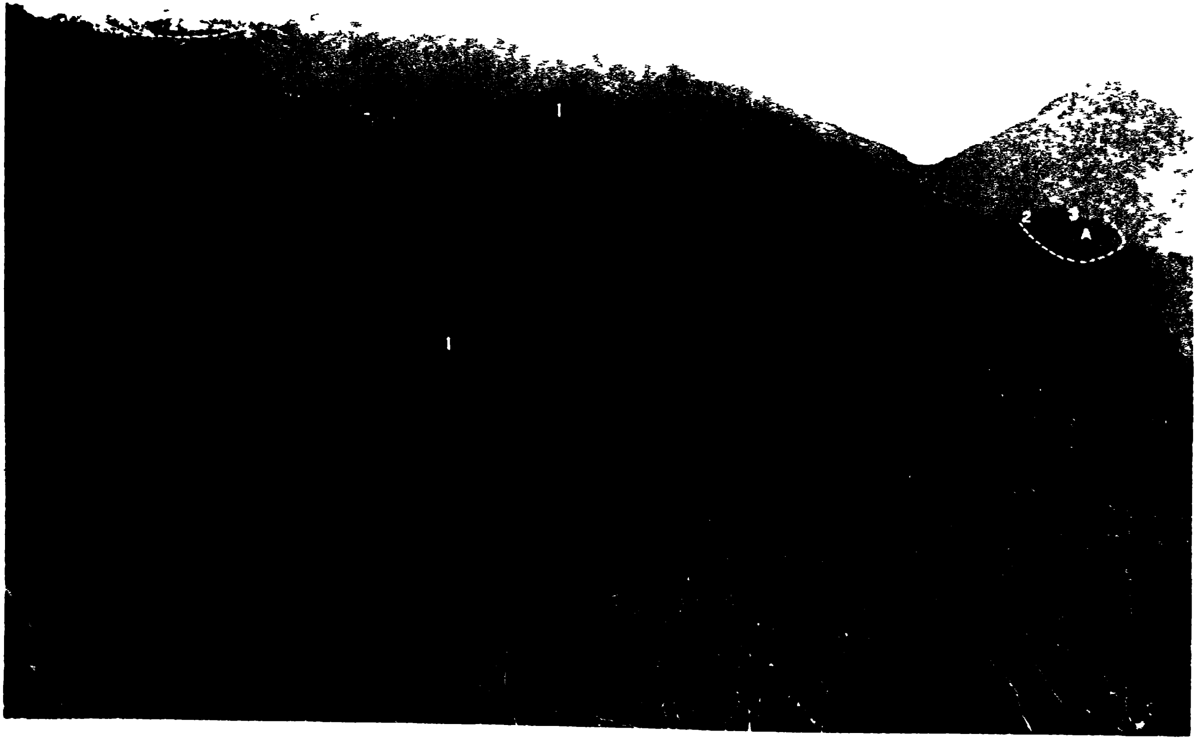
Fig. 2

THE APPROACH TO THE LODHRA COALFIELD JAMMU

PLATE 8.

3. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
1. Blue-grey limestone (pre-Tertiary).
    - A. The Bugoola synclinal.
    - B. The main anticlinal.
    - C. The Sarodabar outlier.

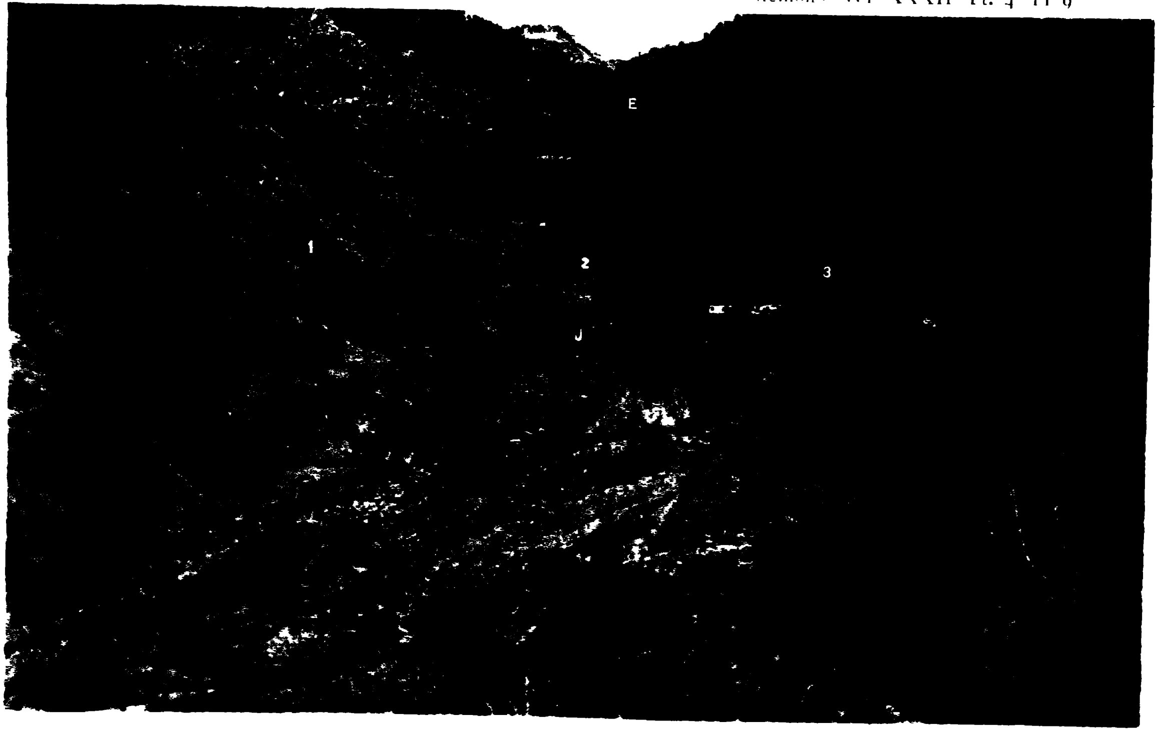
R. R. Simpson



THE EASTERN PORTION OF THE SANGAR MARG COALFIELD JAMMU

PLATE 9.

3. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
1. Blue-grey limestone (pre-Tertiary).
    E. Drives E. and F.
    J. Jungle drive.



JUNGLE RAVINE LADDA COALFIELD JAMMU

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Memoirs, Vol. XXXII, Pt. 4, Pl. 10

SHAFT SINKING SIRÓ VALLEY COALFIELD JAMMU

R. R. Simpson

Memoirs Vol XXXII Pt 4 Pl 11

FAULTING IN THE SIRO VALLEY COALFIELD

[illegible]

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Memoirs, Vol. XXXII, Pt. [illegible]

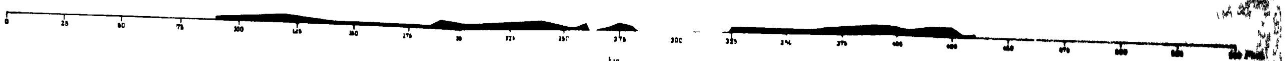

Fig [illegible]

Jungle A drive

The coal averages [illegible] inches between points situated 90 ft. & 415 ft. respectively from the entrance of the tunnel

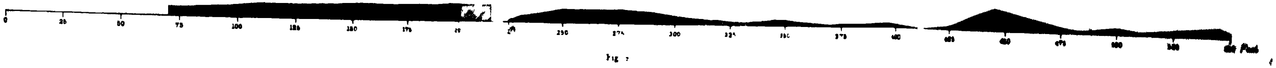

Fig 2

[illegible] Drive

The coal averages [illegible] thickness between points situated [illegible] & 550 ft, respectively from the entrance of the tunnel

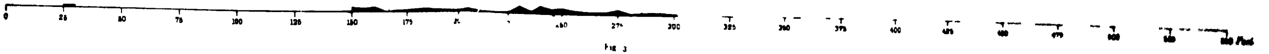

Fig 3

F Drive

The coal averages [illegible] inches in thickness between points situated [illegible] ft & 302 ft respectively from the entrance of the tunnel

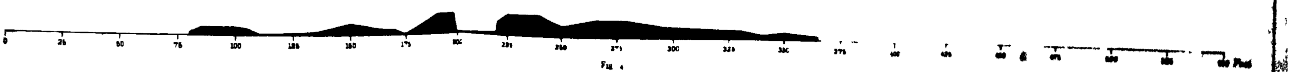

Fig 4

Santrami Kund drive

The coal averages [illegible] inches in thickness between points situated 86 ft, & 350 ft, respectively from the entrance of the tunnel

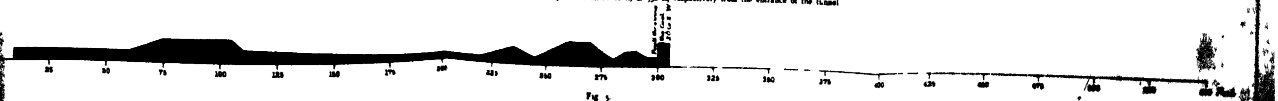

Fig 5

Nadia drive

The coal seam is [illegible] split up by clay bands, not shown on diagram. The coal itself averages 4 ft 9 inches in thickness between points situated 93 ft. & 295 ft, respectively from the entrance of the tunnel.

INDEX

▇ Coal

▇ Coaly Shale

Scale 1" = [illegible] Feet

GRAPHICAL REPRESENTATION OF THE THICKNESS OF COAL ENCOUNTERED IN THE LONG DRIVES IN THE LADDA COALFIELD